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## The Geognosy of the Appalachians and the Origin of Crystalline Rocks.

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ON RETIRING FROM THE OFFICE OF PRESIDENT OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

GENTLEMEN OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE: —

IN coming before you this evening my first duty is to announce the death of Professor William Chauvenet. This sad event was not unexpected, since, at the time of his election to the presidency of the Association, at the close of our meeting at Salem in August, 1869, it was already feared that failing health would prevent him from meeting with us at Troy, in 1870. This, as you are aware, was the case, and I was therefore called to preside over the Association in his stead. In the autumn of 1869, he was compelled by illness to resign his position of Chancellor of the Washington University of St. Louis, and in December last died at the age of fifty years, leaving behind him a record to which science and his country may point with just pride. During his connection of fourteen years with the Naval Academy at Annapolis he was the chief instrument in building up that institution, which he left in 1859 to take the chair of Astronomy and Mathematics at St. Louis, where his remarkable qualities led to his selection, in 1862, for the post of

chancellor of the university, which he filled with great credit and usefulness up to the time of his resignation.* It is not for me to pronounce the eulogy of Professor Chauvenet, to speak of his profound attainments in astronomy and mathematics, or of his published works, which have already taken rank as classics in the literature of these sciences. Others more familiar with his field of labor may in proper time and place attempt the task. All who knew him can however join with me in testifying to his excellencies as a man, an instructor and a friend. In his assiduous devotion to scientific studies he did not neglect the more elegant arts, but was a skilful musician, and possessed of great general culture and refinement of taste. In his social and moral relations he was marked by rare elevation and purity of character, and has left to the world a standard of excellence in every relation of life which few can hope to attain.

In accordance with our custom it becomes my duty in quitting the honorable position of president, which I have filled for the past year, to address you upon some theme which shall be germane to the objects of the Association. The presiding officer, as you are aware, is generally chosen to represent alternately one of the two great sections into which the members of the Association are supposed to be divided; viz., the students of the natural-history sciences on the one hand, and of the physico-mathematical and chemical sciences on the other. The arrangement by which, in our organization, geology is classed with the natural-history division, is based upon what may fairly be challenged as a somewhat narrow conception of its scope and aims. While theoretical geology investigates the astronomical, physical, chemical and biological laws which have presided over the development of our earth, and while practical geology or geognosy studies its natural history, as exhibited in its physical structure, its mineralogy and its paleontology, it will be seen that this comprehensive science is a stranger to none of the studies which are included in the plan of our Association, but rather sits like a sovereign, commanding in turn the services of all.

As a student of geology, I scarcely know with which section of the Association I should to-day identify myself. Let me endeavor

* Amer. Jour. Sci., III, i, 233.

rather to mediate between the two, and show you somewhat of the two-fold aspect which geological science presents, when viewed respectively from the stand-points of natural history and of chemistry. I can hardly do this better than in the discussion of a subject which for the last generation has afforded some of the most fascinating and perplexing problems for our geological students; viz., the history of the great Appalachian mountain chain. Nowhere else in the world has a mountain system of such geographical extent and such geological complexity been studied by such a number of zealous and learned investigators, and no other, it may be confidently asserted, has furnished such vast and important results to geological science. The laws of mountain structure, as revealed in the Appalachians by the labors of the brothers Henry D. and William B. Rogers, of Lesley and of Hall, have given to the world the basis of a correct system of orographic geology,* and many of the obscure geological problems of Europe become plain when read in the light of our American experience. To discuss even in the most summary manner all of the questions which the theme suggests, would be a task too long for the present occasion, but I shall endeavor to-night in the first place to bring before you certain facts in the history of the physical structure, the mineralogy and the paleontology of the Appalachians; and in the second place to discuss some of the physical, chemical and biological conditions which have presided over the formation of the ancient crystalline rocks that make up so large a portion of our great eastern mountain system.

## *I. The Geognosy of the Appalachian System.*

The age and geological relations of the crystalline stratified rocks of eastern North America have for a long time occupied the attention of geologists. A section across northern New York, from Ogdensburg on the St. Lawrence to Portland in Maine, shows the existence of three distinct regions of unlike crystalline schists. These are the Adirondacks to the west of Lake Champlain, the Green Mountains of Vermont, and the White Mountains of New Hampshire. The lithological and mineralogical differences between the rocks of these three regions are such as to have attracted the attention of some of the earlier observers. Eaton, one of the

* Amer. Jour. Sci., II, xxx, 406.

founders of American geology, at least as early as 1832, distinguished in his Geological Text book (2d edition) between the gneiss of the Adirondacks and that of the Green Mountains. Adopting the then received divisions of primary, transition, secondary and tertiary rocks, he divided each of these series into three classes, which he named carboniferous, quartzose and calcareous; meaning by the first schistose or argillaceous strata such as, according to him, might include carbonaceous matter. These three divisions in fact corresponded to clay, sand, and lime-rocks, and were supposed by him to be repeated in the same order in each series. This was apparently the first recognition of that law of cycles in sedimentation upon which I afterwards insisted in 1863.* Without, so far as I am aware, defining the relations of the Adirondacks, he referred to the lowest or carboniferous division of the primary series, the crystalline schists of the Green Mountains, while the quartzites and marbles at their western base were made the quartzose and calcareous divisions of this primary series. The argillites and sandstones lying still farther westward, but to the east of the Hudson River, were regarded as the first and second divisions of the transition series, and were followed by its calcareous division, which seems to have included the limestones of the Trenton group; all of these rocks being supposed to dip to the westward, and away from the central axis of the Green Mountains. Eaton does not appear to have studied the White Mountains, or to have considered their geological relations. They were, however, clearly distinguished from the former by C. T. Jackson in 1844, when, in his report on the geology of New Hampshire, he described the White Mountains as an axis of primary granite, gneiss and mica-schist, overlaid successively, both to the east and west, by what were designated by him Cambrian and Silurian rocks; these names having, since the time of Eaton's publication, been introduced by English geologists. While these overlying rocks in Maine were unaltered, he conceived that the corresponding strata in Vermont, on the western side of the granitic axis, had been changed by the action of intrusive serpentines and intrusive quartzites, which had altered the Cambrian into the Green Mountain gneiss, and converted a portion of the fossiliferous Silurian limestones of the Champlain valley into white marbles.† Jackson did not institute any comparison be-

* Amer. Jour. Sci., II, xxxv, 166.
† Geology of New Hampshire, 160–162.

tween the rocks of the White Mountains and those of the Adirondacks; but the Messrs. Rogers in the same year, 1844, published an essay on the geological age of the White Mountains, in which, while endeavoring to show their Upper Silurian age, they speak of them as having been hitherto regarded as consisting exclusively of various modifications of granitic and gneissoid rocks, and as belonging "to the so-called primary periods of geologic time."* They however considered that these rocks had rather the aspect of altered paleozoic strata, and suggested that they might be, in part at least, of the age of the Clinton division of the New York system; a view which was supported by the presence of what were at the time regarded by the Messrs. Rogers as organic remains. Subsequently, in 1847,† they announced that they no longer considered these to be of organic origin, without however retracting their opinion as to the paleozoic age of the strata. Reserving to another place in my address the discussion of the geological age of the White Mountain rocks, I proceed to notice briefly the distinctive characters of the three groups of crystalline strata just mentioned, which will be shown in the sequel to have an importance in geology beyond the limits of the Appalachians.

I. *The Adirondack or Laurentide Series.* The rocks of this series, to which the name of the Laurentian system has been given, may be described as chiefly firm granitic gneisses, often very coarse-grained, and generally reddish or grayish in color. They are frequently hornblendic, but seldom or never contain much mica, and the mica-schists, (often accompanied with staurolite, garnet, andalusite and cyanite), so characteristic of the White Mountain series, are wanting among the Laurentian rocks. They are also destitute of argillites, which are found in the other two series. The quartzites, and the pyroxenic and hornblendic rocks, associated with great formations of crystalline limestone, with graphite, and immense beds of magnetic iron ore, give a peculiar character to portions of the Laurentian system.

II. *The Green Mountain Series.* The quartzo-feldspathic rocks of this series are to a considerable extent represented by a fine-grained petrosilex or eurite, though they often assume the form of a true gneiss, which is ordinarily more micaceous than the typical

* Amer. Jour. Sci., II, i, 411.
† Ibid, II, v, 116.

Laurentian gneiss. The coarse-grained, porphyritic, reddish varieties common to the latter are wanting in the Green Mountains, where the gneiss is generally of pale greenish and grayish hues. Massive stratified diorites, and epidotic and chloritic rocks, often more or less schistose, with steatite, dark colored serpentines and ferriferous dolomites and magnesites also characterize this gneissic series, and are intimately associated with beds of iron ore, generally a slaty hematite, but occasionally magnetite. Chrome, titanium, nickel, copper, antimony and gold are frequently met with in this series. The gneisses often pass into schistose micaceous quartzites, and the argillites, which abound, frequently assume a soft, unctuous character, which has acquired for them the name of talcose or nacreous slates, though analysis shows them not to be magnesian, but to consist essentially of a hydrous micaceous mineral. They are sometimes black and graphitic.

III. *The White Mountain Series.* This series is characterized by the predominance of well defined mica-schists interstratified with micaceous gneisses. These latter are ordinarily light colored from the presence of white feldspar, and, though generally fine in texture, are sometimes coarse-grained and porphyritic. They are less strong and coherent than the gneisses of the Laurentian, and pass, through the predominance of mica, into mica-schists, which are themselves more or less tender and friable, and present every variety, from a coarse gneiss-like aggregate down to a fine-grained schist, which passes into argillite. The micaceous schists of this series are generally much richer in mica than those of the preceding series, and often contain a large proportion of well defined crystalline tables belonging to the species muscovite. The cleavage of these micaceous schists is generally, if not always, coincident with the bedding, but the plates of mica in the coarser-grained varieties are often arranged at various angles to the cleavage and bedding-plane, showing that they were developed after sedimentation, by crystallization in the mass; a circumstance which distinguishes them from rocks derived from the ruins of these, which are met with in more recent series. The White Mountain rocks also include beds of micaceous quartzite. The basic silicates in this series are represented chiefly by dark colored gneisses and schists, in which hornblende takes the place of mica. These pass occasionally into beds of dark hornblende-rock, sometimes holding garnets. Beds of crystalline limestone occasionally occur in the

schists of the White Mountain series, and are sometimes accompanied by pyroxene, garnet, idocrase, sphene and graphite, as in the corresponding rocks of the Laurentian, which this series, in its more gneissic portions, closely resembles, though apparently distinct geognostically. The limestones are intimately associated with the highly micaceous schists containing staurolite, andalusite, cyanite and garnet. These schists are sometimes highly plumbaginous, as seen in the graphitic mica-schist holding garnets in Nelson, New Hampshire, and that associated with cyanite in Cornwall, Conn. To this third series of crystalline schists belong the concretionary granitic veins abounding in beryl, tourmaline and lepidolite, and occasionally containing tinstone and columbite. Granitic veins in the Laurentian gneisses frequently contain tourmaline, but have not, so far as yet known, yielded the other mineral species just mentioned.*

Keeping in mind the characteristics of these three series, it will be easy to trace them southward by the aid of the concise and accurate descriptions which Prof. H. D. Rogers has given us of the rocks of Pennsylvania. In his report on the geology of this state he has distinguished three districts of various crystalline schists, which are by him included together under the name of gneissic or hypozoic rocks. Of these districts the most northern, or the South Mountain belt, to the northwest of the Mesozoic basin, is said to be the continuation of the Highlands of New York and New Jersey, which, crossing the Delaware near Easton, is continued southward through Pennsylvania and Maryland into Virginia, where it appears in the Blue Ridge. The gneiss of this district in Pennsylvania is described as differing considerably from that of the southernmost district, being massive and granitoid, often hornblendic, with much magnetic iron, but destitute of any considerable beds of micaceous, talcose or chloritic slate, which mark the rocks of the southern district. These characters are sufficient to show that the gneiss of this northern district is lithologically as well as geognostically identical with that of the Highlands, and belongs like it to the Adirondack or Laurentian system of crystalline rocks. The gneiss of the middle district of Pennsylvania, to the south of the Mesozoic, but north of the Chester valley, is described by Rogers as resembling that of the South Mountain or

* Hunt, Notes on Granitic Rocks; Amer. Jour. Sci., III, i, 182.

northern district, and to consist chiefly of white feldspathic and dark hornblendic gneiss, with very little mica, and with crystalline limestones.

The gneiss of the third or southern district, that lying to the south of the Montgomery and Chester valleys, comes from beneath the Mesozoic of New Jersey about six miles northeast of Trenton, and stretching southwestward, occupies the southern border of Pennsylvania, extending into Delaware and Maryland. It is subdivided by Rogers into three belts; the first or southernmost of these, passing through Philadelphia, consists of alternations of dark hornblendic and highly micaceous gneiss, with abundance of mica-slate, sometimes coarse-grained, and at other times so fine-grained as to constitute a sort of whet-slate. To the northwestward the strata become still more micaceous, with garnets and beds of hornblende slate, till we reach the second subdivision, which consists of a great belt of highly talcose and micaceous schists, with steatite and serpentine, and is in its turn succeeded by a third, narrow belt resembling the less micaceous members of the first or southernmost subdivision. The micaceous schists of this region abound in staurolite, garnet, cyanite and corundum, and are traversed by numerous irregular granitic veins containing beryl and tourmaline. All of these characters lead us to refer the gneiss of this southern district to the third or White Mountain series, with the exception of the middle subdivision, which presents the aspect of the second or Green Mountain series.

Above the hypozoic gneisses Rogers has placed his azoic or semi-metamorphic series, which is traceable from the vicinity of Trenton to the Schuylkill, along the northern boundary of the southern hypozoic gneiss district. This series is supposed by Rogers to be an altered form of the primal sandstones and slates, and is described as consisting of a feldspathic quartzite or eurite, containing in some cases porphyritic beds with crystals of feldspar and hornblende, together with various crystalline schists; including in fact the whole of the great serpentine belt of Montgomery, Chester and Lancaster counties, with its steatites, hornblendic, dioritic, chloritic, and micaceous schists (often garnet-bearing), together with a band of argillite, affording roofing-slates. With this great series are associated chromic and titanic iron, and ores of nickel and copper. Veins of albite with corundum also intersect this series near Unionville. We are repeatedly assured by

Rogers that these rocks so much resemble the underlying hypozoic gneiss, as to be readily confounded with them; and when compared with the latter, as displayed in the southern district, it is difficult to believe that we have in this so-called azoic or metamorphic series of the Montgomery and Chester valleys, anything else than a repetition of these same crystalline schists which have been described along their southern boundary, representing the Green Mountain and the White Mountain series. We thus avoid the difficulty of supposing that we have in this region two sets of serpentinic rocks, and two of mica-schists, lithologically similar, but of widely different ages,—a conclusion highly improbable. It should be said that Rogers, in accordance with the notions then generally received, looked upon serpentine as an eruptive rock, which had altered the adjacent strata, converting the mica-schists into steatitic and chloritic rocks.

This so-called azoic series, according to Rogers, underlies the auroral limestone of Pennsylvania, thus apparently occupying the horizon of the primal paleozoic division or Potsdam series. We find, however, in his report on the geology of the state, no satisfactory evidence of the identity of the two series. On the contrary, a very different conclusion would seem to follow from certain facts there detailed. The azoic or so-called metamorphic primal strata are said to have a very uniform nearly vertical dip, or with high angles to the southward, while the micaceous and gneissic strata of the northern subdivision of the southern district of so-called hypozoic rocks, limiting these last to the south, present either minute local contortions or wide gentle undulations, with comparatively moderate dips, for the most part to the northward.* From this, I think we may infer that the nearly vertical strata must be, in truth, older underlying rocks belonging, not to the paleozoic system, but to our second series of crystalline schists. We conclude, then, that while the gneisses to the northwest, and probably those along the southeast rim of the Mesozoic basin of Pennsylvania are Laurentian, the great valley southward to the Delaware is occupied by the rocks of the Green Mountain and White Mountain series. The same two types of rocks, extending to the northeast, are developed about New York city, in the mica-schists of Manhattan and the serpentines of Staten Island and Hoboken;

* Rogers, Geology of Pennsylvania, I. pp. 69–74, and 154–158.

while in the range of the Highlands, the gneiss belt of the South Mountain crosses the Hudson river.

The three series of gneissic rocks which we have distinguished in our section to the northward have, in southeastern New York, as in Pennsylvania, been grouped together in the primary system, and may thence all be traced into western New England. In Dr. Percival's geological report and map of Connecticut, published in 1840, it will be seen that he refers to the gneiss of the Highlands two gneissic areas in Litchfield county; the one occupying parts of Cornwall and Ellsworth, and the other extending from Torrington, northward through Winchester, Norfolk and Colebrooke into Berkshire county, Massachusetts. Farther investigations may confirm the accuracy of Percival's identification, and show the Laurentian age of these New England gneisses, a view which is apparently supported by the mineralogical characters of some of the rocks in this region. Emmons informs us that primary limestones with graphite, (perhaps Laurentian), are met with in the Hoosic range in Massachusetts east of the Stockbridge (Taconic) limestones.

The rocks of the second series are traceable from southwestern Connecticut northward to the Green Mountains in Vermont, and the micaceous schists and gneisses of the third or White Mountain series are found both to the east and the west of the Mesozoic valley in Connecticut and Massachusetts. They also occupy a considerable area in eastern Vermont, where they are separated from the White Mountain range by an outcrop of rocks of the second series. To the southeast of the White Mountains, along our line of section, the same mica-schists and gneisses, often with very moderate dips, extend as far as Portland, Maine, where they are interrupted by the outcropping of greenish chloritic and chromiferous schists, in nearly vertical beds, which appear to belong to the second series.

I find that the strata of the second series appear from beneath the Carboniferous at Newport, Rhode Island, in a nearly vertical attitude, and also in the vicinity of Boston and Brighton, Saugus and Lynnfield. Their relations in this region to the gneisses with crystalline limestones of Chelmsford, etc., which I have referred to the Laurentian series,* have yet to be determined.

We have already mentioned that the crystalline rocks of Pennsylvania pass into Maryland and Virginia, where, as H. D. Rogers

* Amer. Jour. Sci., II, xlix, 75.

informs us, they appear in the mountains of the Blue Ridge. It remains to be seen whether the three types which we have pointed out in Pennsylvania are to be recognized in this region. A great belt of crystalline schists extends from Virginia through North and South Carolina, and into eastern Tennessee, where, according to Safford, these rocks underlie the Potsdam. It is easy, from the reports of Lieber on the geology of South Carolina, to identify in this state the two types of the Green Mountain and White Mountain series. The former, as described by him, consists of talcose, chloritic and epidotic schists, with diorites, steatites, actinolite-rock and serpentines. It may be noted that he still adheres to the notion of the eruptive origin of the last three rocks, which the observations of Emmons, Logan and myself in the Green Mountains have shown to be untenable. These rocks in South Carolina generally dip at very high angles. The great gneissic area of Anderson and Abbeville districts is described by Lieber as consisting of fine-grained grey gneisses with micaceous and hornblendic schists, and is cut by numerous veins of pegmatite, holding garnet, tourmaline and beryl. These rocks, which have the characters of the White Mountain series, appear, from the incidental observations to be found in Lieber's reports, to belong to a higher group than the chloritic and serpentinic series, and to dip at comparatively moderate angles.

Professor Emmons, whose attention was early turned to the geology of western New England, did not distinguish between the three types which we have defined, but, like Rogers in Pennsylvania, included all the crystalline rocks of that region in the primary system. It is to him, however, that we owe the first correct notions of the geological nature and relations of the Green Mountains. These, he has remarked, are often made to include two ranges of hills belonging to different geological series. The eastern range, including the Hoosic Mountain in Massachusetts, and Mount Mansfield in Vermont, he referred to the primary; which he described as including gneiss, mica-schist, talcose slate and hornblende, with beds and veins of granite, limestone, serpentine and trap. He declared, moreover, that there is no clear line of demarcation among the various schistose primary rocks, and cited, as an illustration, the passage into each other of serpentine, steatite and talcose schist. His description of the crystalline rocks of this range will be recognized as comprehensive and truthful.

To the west of the hills of primary schist, he placed his Taconic system, named from the Taconic hills, which run from north to south along the boundary line of New York and Massachusetts and form a range parallel with the Green Mountains. The lower portions of the Taconic system, according to Emmons, are schistose rocks made up from the ruins of the primary schists which lie to the east of them. Thus the talcose schists of Berkshire are said to be regenerated rocks, belonging to the newer system, but showing the color and texture of the older talcose schists from which they were formed. How far this is true of these particular strata may be a question, for there is reason to believe that Emmons included among his Taconic rocks some beds belonging to the older crystalline series of the Green Mountains; yet it is not less true that the possibility of derived rocks of this kind is one which has been too much overlooked by geologists. Emmons elsewhere remarks that while the talcose slates of the primary are associated with steatite and with hornblende, these are never found in the Taconic rocks, and also, that epidote, actinolite, titanium (rutile), etc., which are characteristic minerals of the primary, are wanting in the Taconic system.

The statements of Emmons on this point, were sufficiently explicit; he included in the primary system all of the crystalline schists of the Green Mountains, except certain talcose and micaceous beds, which he supposed to be composed from the ruins of similar strata in the primary, and to constitute, with a great mass of other rocks, the Taconic system; which was, in its turn, unconformably overlaid by the Potsdam sandstone and Calciferous sandrock of the New York system. His views have, however, been misunderstood by more than one of his critics; thus, Mr. Marcou, while defending the Taconic system, makes it to include the three groups just mentioned, viz.: I, the Green Mountain gneiss; II, the Taconic strata as defined by Emmons, and III, the Potsdam sandstone,* thus uniting in one system the crystalline schists and the overlying uncrystalline fossiliferous sediments, in direct opposition to the plainly expressed teachings of Emmons, as laid down in his report on the Geology of the Northern District of New York, and later, in 1846,† in his work on the Taconic system.

In the geological survey of the state of New York, the rocks of

* Proc. Bost. Nat. Hist. Soc., Nov. 6, 1861, and Amer. Jour. Sci., II, xxxiii, 282.
† Loc. cit., p. 139, and Agricult., N. York, I, 53.

the Champlain division, including the strata from the base of the Potsdam sandstone to the summit of the Loraine or Hudson River shales, had, by his colleagues, been looked upon as the lowest of the paleozoic system. Professor Emmons, however, was led to regard the very dissimilar strata of the Taconic hills as constituting a distinct and more ancient series. A similar view had been held by Eaton, who placed, as we have already seen, above the crystalline schists of the Green Mountains, his primary quartzose and calcareous formations, followed to the westward by transition argillites and sandstones, which latter appear to have corresponded to the Potsdam sandstone of New York. Emmons, however, gave a greater form and consistency to this view, and endeavored to sustain it by the evidence of fossils, as well as by structure. The Taconic system, as defined by him, may be briefly described as a series of uncrystalline fossiliferous sediments reposing unconformably on the crystalline schists of the Green Mountains, and partly made up of their ruins; while it is, at the same time, overlaid unconformably by the Potsdam and Calciferous formations of the Champlain division, and constitutes the true base of the paleozoic column, — thus occupying the position of the British Cambrian.

Although he claimed to have traced this Taconic system throughout the Appalachian chain from Maine to North Carolina, it is along the confines of Massachusetts and New York that its development was most minutely studied. He divided it into a lower and an upper division, and estimated its total thickness at not less than thirty thousand feet, consisting, in the order of deposition, of the following members: — 1. Granular quartz; 2. Stockbridge limestone; 3. Magnesian slate; 4. Sparry limestone; 5. Roofing-slate, graptolitic; 6. Silicious conglomerate; 7. Taconic slate; 8. Black slate. The apparent order of superposition differs from this, and it was conceived by Professor Emmons that during the accumulation of these Taconic rocks, the Green Mountain gneiss, which formed the eastern border of the basin, was gradually elevated so as to bring successively the older members above the ocean from which the sediments were being deposited. From this it resulted that the upper members of the system, such as the black slates, were confined to a very narrow belt, and never extended far eastward; although he admits that denudation may have removed large portions of these upper beds. At a subsequent period, a series of parallel faults, with upthrows on the eastern side, is supposed to

have broken the strata, given them an eastward dip, and caused the newer beds to pass successively beneath the older ones, thus producing an *apparently inverted succession*, and making their present seeming order of superposition completely deceptive. In speaking of this supposed arrangement of the members of his Taconic system, Emmons alluded to them as "inverted strata;" while by Mr. Marcou, the strata were said to be "overturned on each side of the crystalline and eruptive rocks which occupy the centre of the chain, producing thus a fan-shaped structure," etc.* I have elsewhere shown that this notion, though to some extent countenanced by his vague and inaccurate use of terms, was never entertained by Emmons, whose own view, as defined in his *Taconic System* (p. 17).† is that just explained.

The view of Emmons that there exists at the western base of the Green Mountains, older fossiliferous series underlying the Potsdam, met with general opposition from American geologists. In May, 1844, H. D. Rogers, in his address as President, before the American Association of Geologists, then met at Washington, criticised this view at length, and referred to a section from Stockbridge, Massachusetts, to the Hudson River, made by W. B. Rogers and himself, and by them laid before the American Philosophical Society in January, 1841. They then maintained that the quartz-rock of the Hoosic range was Potsdam, the Berkshire marble identical with the blue limestone of the Hudson valley, and the associated micaceous and talcose schists, altered strata of the age of the slates at the base of the Appalachian system; that is to say, primal in the nomenclature of the Pennsylvania survey.

In 1843 Mather had asserted the Champlain age of the same crystalline rocks, and claimed that the whole of the division was there represented, including the Potsdam, the Hudson River group, and the intermediate limestones. ‡ The conclusion of Mather was cited with approbation by Rogers, who apparently adopted it, and

* Comptes Rendus de l'Acad., LIII. 804.

† See my farther discussion of the matter, Amer. Jour. Sci., II. xxxii. 427. xxxiii, 135, 281. It is by an oversight that I have, in the latter volume, page 136, represented Barrande as sharing the misconception of Marcou, although his language, without careful scrutiny, would lead us to such a conclusion. In fact in the Bull. Soc. Geol. de France (II, xviii. 251), in an elaborate study of the Taconic question, Barrande heads a section thus, "*Renversement conçu pour tout un système*," and then proceeds to show that the *renversement* or *overturn* is only apparent, by explaining, in the language of Emmons, the view already set forth above.

‡ Geology of the Southern District of New York, p. 438.

claimed that Hitchcock held a similar view. It will be seen that these geologists thus united in one group, the schists of the Hoosic range (regarded by Emmons as primary), with those of the Taconic range, and referred both to the age of the Champlain division, the whole of which was supposed to be included in the group.

In the same address Professor Rogers raised a very important question. Having referred to the Potsdam sandstone, which on Lake Champlain forms the base of the paleozoic system, he inquires, "Is this formation then the lowest limit of our Appalachian masses generally, or is the system expanded downward in other districts by the introduction beneath it of other conformable sedimentary rocks?" He then proceeded to state that from the Susquehanna River, southwestward, a more complex series appears at the base of the lower limestone than to the north of the Schuylkill, and in some parts of the Blue Ridge he includes in the primal division (beneath the Calciferous sandrock) "at least four independent and often very thick deposits, constituting one general group, in which the Potsdam or white sandstone (with Scolithus) is the second in descending order." This sandstone is overlaid by many hundred feet of arenaceous and ferriferous fucoidal slate, and underlaid by coarse sandy shales and flagstones; below which, in Virginia and East Tennessee, is a series of heterogeneous conglomerates, which rest on a great mass of crystalline strata. The accuracy of these statements is confirmed by Safford, who, in his recent report on the geology of Tennessee (1869), places at the base of the column a great series of crystalline schists, apparently representatives of those of southeastern Pennsylvania. Upon these repose what Safford designates as the Potsdam group, including, in ascending order, the Ococee slates and conglomerates, estimated at 10,000 feet, and the Chilhowee shales and sandstones, 2,000 feet or more, with fucoids, worm-burrows and Scolithus. These are conformably overlaid by the Knoxville division, consisting of fucoidal sandstones, shales, and limestones, the latter two holding fossils of the age of the Calciferous sandrock. It is noteworthy that these rocks are greatly disturbed by faults, and that in Chilhowee Mountain the lower conglomerates are brought on the east against the Carboniferous limestone, by a vertical displacement of at least 12,000 feet. The general dip of all these strata, including the basal crystalline schists, is to the southeast.

The primal paleozoic rocks of the Blue Ridge were then by Rog-

ers, as now by Safford, looked upon as wholly of Potsdam age, including the Scolithus sandstone as a subordinate member, so that the strata beneath this were still regarded as belonging to the New York system. Hence, while Rogers inquires whether the Taconic system "may not along the western border of Vermont and Massachusetts include also some of the sandy and slaty strata here spoken of as lying beneath the Potsdam sandstone"* he would still embrace these lower strata in the Champlain division.

Thus we see that at an early period the rocks of the Taconic system were, by Rogers and Mather, referred to the Champlain division of the New York system, a conclusion which has been sustained by subsequent observations. Before discussing these, and their somewhat involved history, we may state two questions which present themselves in connection with this solution of the problem. First, whether the Taconic system, as defined by Emmons, includes the whole or a part of the Champlain division; and second, whether it embraces any strata older or newer than the members of this portion of the New York system. With reference to the first question it is to be remarked that in their attempts to compare the Taconic rocks with those of the Champlain division as seen farther to the west, observers were led by lithological similarities to identify the upper members of the latter with certain portions of the Taconic. In fact, the Trenton limestone, with the Utica slates and the Loraine or Hudson River shales, making together the upper half of the Champlain division (in which Emmons moreover included the overlying Oneida and Medina conglomerates and sandstones), have in New York an aggregate thickness of not less than three or four thousand feet, and offer many lithological resemblances to the great mass of sediments at the western base of the Green Mountains, to which the name of Taconic had been applied. It is curious to find that Emmons, in 1842, referred to the Medina the Red sandrock of the east shore of Lake Champlain, since shown to be Potsdam†; and, moreover, placed the Sillery sandstone of the neighborhood of Quebec at the summit of the Champlain division, as the representative of the Oneida conglomerate; while at the same time he noticed the great resemblance which this sandstone, with its adjacent limestones, bore to similar rocks on the confines of Massachusetts, already referred by him to the Taconic system.†

* Amer. Jour. Sci., I, xlvii, 152, 153.

† Geol. Northern District of New York, pp. 124, 125.

This view of Emmons as to the Quebec rocks was adopted by Sir William Logan, when, a few years afterwards, he began to study the geology of that region. The sandstone of Sillery was described by him as corresponding to the Oneida or Shawangunk conglomerate, while the limestones and shales of the vicinity, which were supposed to underlie it, were regarded as the representatives of the Trenton, Utica, and Hudson River formations.* By following these rocks along the western base of the Appalachians into Vermont and Massachusetts, they were found to be a continuation of the Taconic system, which Sir William was thus led to refer to the upper half of the Champlain division, as had already been done by Professor Adams in 1847.† As regards the crystalline strata of the Appalachians in this region, he, however, rejected the view of Emmons, and maintained that put forward by the Messrs. Rogers in 1841, viz., that these, instead of being older rocks, were but these same upper formations of the Champlain division in an altered condition; a view which was maintained during several years in all of the publications of those connected with the geological survey of Canada.

This conclusion, so far as regards the age of the unaltered fossiliferous rocks from Quebec to Massachusetts, was supposed to be confirmed by the evidence of organic remains found in them in Vermont. Mr. Emmons had described as characteristic of the upper part of the Taconic system, two crustaceans, to which he gave the names of *Atops trilineatus* and *Elliptocephalus asaphoides;* the other fossils noticed by him being graptolites, fucoids, and what were apparently the marks of annelids. In 1847 Professor James Hall, in the first volume of his Paleontology, declared the Atops of Emmons to be identical with *Triarthrus* (*Calymene*) *Beckii*, a characteristic fossil of the Utica slate; while the Elliptocephalus was referred by him to the genus *Olenus*, now known to belong to the primordial fauna of Sweden, where it is found in slates lying beneath the orthoceratite limestone, and near the base of the paleozoic series. Although, as it now appears, the geological horizon of the Olenus slates was well known to Hisinger, this author in his classic work, *Lethæa Suecica*, published in 1837, represents, by some unexplained error, these slates as overlying the orthoceratite

*Geol. Survey of Canada, 1847-48, pp. 27, 57; and Amer. Jour. Sci., II, ix, 12.
†Amer. Jour. Sci., II, v, 108.

limestone, which is the equivalent of the Trenton limestone of the Champlain division. Hence, as Mr. Barrande has remarked, Hall was justified by the authority of Hisinger's published work in assigning to the Olenus slates of Vermont a position above that limestone, and in placing them, as he then did, on the horizon of the Hudson River or Loraine shales. The double evidence afforded by these two fossil forms in the rocks of Vermont, served to confirm Sir William Logan in placing in the upper part of the Champlain division the rocks which he regarded as their stratigraphical equivalents near Quebec; and which, as we have seen, had some years before been by Emmons himself assigned to the same horizon. The remarkable compound graptolites which occur in the shales of Pointe Levis, opposite Quebec, were described by Professor James Hall in the report of the Geological Survey of Canada for 1857, and were then referred to the Hudson River group; nor was it until August, 1860, that Mr. Billings described from the limestones of this same series at Pointe Levis a number of trilobites, among which were several species of Agnostus, Dikelocephalus, Bathyurus, etc., constituting a fauna whose geological horizon he decided to be in the lower part of the Champlain division.

Just previous to this time, in the Report of the Regents of the University of New York for 1859, Professor Hall had described and figured by the name of Olenus, two species of trilobites from the slates of Georgia, Vermont, which Emmons had wrongly referred to the genus Paradoxides. They were at once recognized by Barrande, who called attention to their primordial character, and thus led to a knowledge of their true stratigraphical horizon, and to the detection of the singular error in Hisinger's book, already noticed, by which American geologists had been misled.* They have since been separated from Olenus, and by Professor Hall referred to a new and closely related genus, which he has named Olenellus, and which is now regarded as belonging to the horizon of the Potsdam sandstone, to which we shall presently advert.

Farther studies of the fossiliferous rocks near Quebec showed the existence of a mass of sediments estimated at about 1200 feet, holding a numerous fauna, and corresponding to a great development of strata about the age of the Calciferous and Chazy formations, or more exactly to a formation occupying a position

*For the correspondence on this matter between Barrande, Logan and Hall, see Amer. Jour. Sci., II, xxxi, 210–226.

between these two, and constituting, as it were, beds of passage between them. In this new formation were included the graptolites already described by Hall, and the numerous crustacea and brachiopoda described by Billings, all of which belong to the Levis slates and limestones. To these and their associated rocks Sir William Logan then gave the name of the Quebec group, including, besides the fossiliferous Levis formation, a great mass of overlying slates, sandstones and magnesian limestones, hitherto without fossils, which have been named the Lauzon rocks, and the Sillery sandstones and shales, which he supposed to form the summit of the group, and which had afforded only an Obolella and two species of Lingula;* the volume of the whole group being about 7000 feet.

The paleontological evidence thus obtained by Billings and by Hall, both from near Quebec and in Vermont, led to the conclusion that the strata of these regions, so much resembling the upper members of the Champlain division, were really a great development, in a modified form, of some of its lower portions. Their apparent stratigraphical relations were explained by Logan by the supposition of "an overturned anticlinal fold, with a crack and a great dislocation running along the summit, by which the Quebec group is brought to overlie the Hudson River group. Sometimes it may overlie the overturned Utica formation, and in Vermont points of the overturned Trenton appear occasionally to emerge from beneath the overlap." He, at the same time, declared that "from the physical structure alone, no person would suspect the break that must exist in the neighborhood of Quebec, and, without the evidence of fossils, every one would be authorized to deny it."†

The rocks from western Vermont, which had furnished to Hall the species of Olenellus, have long been known as the Red sandrock, and as we have seen, were by Emmons, in 1842, referred to the age of the Medina sandstone, a view which the late Professor Adams still maintained as late as 1847.‡ In the mean time Emmons had, in 1855, declared this rock to represent the Calciferous and Potsdam formations, the brown sandstones of Burlington and Charlotte, Vermont, being referred to the latter.§

*See Billings, Paleozoic Fossils of Canada, p. 69.

†Logan's letter to Barrande, Amer. Jour. Sci., II. xxxi. 218. The true date of this letter was December 31st, 1830, but, by a misprint, it is made 1831.

‡Adams, Amer. Jour. Sci., II. v. 108.

§Emmons, American Geology, II. 128.

This conclusion was confirmed by Billings, who, in 1861, after visiting the region and examining the organic remains of the Red sandrock, assigned to it a position near the horizon of the Potsdam.* Certain trilobites found in this Red sandrock by Adams in 1847, were by Hall recognized as belonging to the European genus *Conocephalus* (= *Conocephalites* and *Conocoryphe*), whose geological horizon was then undetermined.† The formation in question consists in great part of a red or mottled granular dolomite, associated with beds of fucoidal sandstone, conglomerates and slates. These rocks were carefully examined by Logan in Swanton, Vermont, where, according to him, they have a thickness of 2200 feet, and include toward their base a mass of dark colored shales holding Olenellus with Conocephalites, Obolella, etc.; *Conocephalites Teucer*, Billings, being common to the shales and the red sandy beds.‡ Many of these fossils are also found at Troy and at Bald Mountain, New York, where they accompany the Atops of Emmons, now recognized by Billings as a species of Conocephalites.

A similar condition of things extends northeastward along the Appalachian region. On the south side of the St. Lawrence below Quebec a great thickness of limestones, sandstones, and slates, formerly referred to the Quebec group, is now regarded by Billings as, in part at least, of the Potsdam formation; while on the coast of Labrador, and in northern Newfoundland the same formation, characterized by the same fossils as in Vermont, is largely developed, attaining in some parts, according to Murray, a thickness of 3000 feet or more. Along the northern coast of the island it is nearly horizontal, and appears to be conformably overlaid by about 4000 feet of fossiliferous strata representing the Calciferous sandrock and the succeeding Levis formation.

Mr. Billings has described a section from the Laurentian of Crown Point, New York, to Cornwall, Vermont, from which it appears that to the eastward of a dislocation which brings up the Potsdam to overlie the higher members of the Champlain division, the Potsdam is itself overlaid, at a small angle, by a great mass of limestones representing the Calciferous, and having at the summit some of the characteristic fossils of the Levis formation. Next in

*Amer. Jour. Sci., II, xxxii, 232.
†Ibid., II, xxxiii, 374.
‡Geology of Canada, 1863, p. 281. Amer. Jour. Sci., II, xlvi, 224.

ascending order are not less than 2000 feet of limestones with Trenton fossils (embracing probably the Chazy division), while to the east of this the Levis again appears, including the white Stockbridge limestones.* We have here an evidence that the augmentation in volume observed in the lower members of the Champlain division in the Appalachian region extends to the Trenton, which to the west of Lake Champlain is represented, the Chazy included, by not more than 500 feet of limestone. The Potsdam, in the latter region, consists of from 500 to 700 feet of sandstone holding Conocephalites and Lingulella, and overlaid by 300 feet of magnesian limestone, the so-called Calciferous sandrock. In the valley of the Mississippi these two formations in Iowa, Missouri, and Texas, are represented by from 800 to 1300 feet of sandstones and magnesian limestones, while in the Black Hills of Nebraska, according to Hayden, the only representative of these lower formations is about one hundred feet of sandstone holding Potsdam fossils.†

In striking contrast to this it has been shown that along the Appalachian range from Newfoundland to Tennessee these lower formations are represented by from 8000 to 15000 feet of fossiliferous sediments. It has been suggested by Logan that these widely differing conditions represent deep-sea accumulations on the one hand, and the deposits from a shallow sea which covered a submerged continental plateau, on the other; the sediments in the two areas being characterized by a similar fauna, though differing greatly in lithological characters and in thickness. To this we may add that the continental area, being probably submerged and elevated at intervals, became overlaid with beds which represent only in a partial and imperfect manner the great succession of strata which were being accumulated in the adjacent ocean.‡

In a paper which I hope to present to the geological section during the present meeting of the Association it will be shown from a study of the rocks of the Ottawa basin that the typical Champlain division not only presents important paleontological breaks, but evidences of statigraphical discordance at more than one horizon over the continental area, which, as the result of widely spread movements, might be supposed to be represented in the Appalachian region. In the latter Logan has already observed

* Amer. Jour. Sci., 227.
† Ibid., II, xxv, 439, xxxi, 234.
‡ Ibid., II, xlvi, 225.

that the absence of all but the highest beds of the Levis along the eastern limit of the Potsdam, near Swanton, Vermont, while the whole thickness of them appears a little farther westward, makes it probable that there is a want of conformity between the two; and I have in this connection insisted upon the entire absence in this locality of the Calciferous, which is met with a little farther south in the section just mentioned, as another evidence of the same unconformity.* There are also, I think, reasons for suspecting another stratigraphical break at the summit of the Quebec group, in which case many problems in the geological structure of this region will be much simplified.

It should be remembered that the conditions of deposition in some areas have been such that accumulations of strata, corresponding to long geologic periods, and elsewhere marked by stratigraphical breaks, are arranged in conformable superposition; and moreover that movements of elevation and depression have even caused great paleontological breaks, which over considerable areas are not marked by any apparent discordance. Thus the remarkable break in the fauna between the Calciferous and the Chazy is not accompanied by any noticeable discordance in the Ottawa basin, and in Nebraska, according to Hayden, the Potsdam, Carboniferous, Jurassic and Cretaceous formations are all represented in about 1200 feet of conformable strata.† In Sweden the whole series from the base of the Cambrian to the summit of the Upper Silurian appears as a conformable sequence, while in North Wales, although there is no apparent discordance from the base of the Cambrian to the summit of the Lingula flags, stratigraphical breaks, according to Ramsay, probably occur both at the base and the summit of the Tremadoc slates,‡ which are considered equivalent to the Levis formation.

We have seen that, according to Logan, a dislocation a little to the north of Lake Champlain causes the Quebec group to overlie the higher members of the Champlain division. The same uplift, according to him, brings up, farther south, the Red sandrock of Vermont, which to the west of the dislocation rests upon the upturned and inverted strata of various formations from the Calciferous sandrock to the Utica and Hudson River shales. These

* Amer. Jour. Sci., II, xlvi, 225.
† Ibid., II, xxv, 440.
‡ Quar. Geol. Journal, xix, page xxxvi.

latter, according to him, are seen to pass for considerable distances beneath nearly horizontal layers of the Red sandrock, the Utica slate, in one case, holding its characteristic fossil, *Triarthrus Beckii*. This relation, which is well shown in a section at St. Albans, figured by Hitchcock,* was looked upon by Emmons and by Adams as evidence that the Red sandrock was the representative of the Medina sandstone of the New York system. When, however, the former had recognized the Potsdam age of the sandrock, with its Olenellus, which he supposed to be Paradoxides, this condition of things was conceived to be an evidence of the existence beneath the Potsdam of an older and unconformable fossiliferous series already mentioned.

The objections made by Emmons to Rogers's view of the Champlain age of the Taconic rocks were three-fold: first, the great differences in lithological characters, succession and thickness, between these and the rocks of the Champlain division as previously known in New York; second, the supposed unconformable infraposition of a fossiliferous series to the Potsdam; and third, the distinct fauna which the Taconic rocks were supposed to contain. The first of these is met by the fact now established that in the Appalachian region, the Champlain division is represented by rocks having, with the same organic remains, very different lithological characters, and a thickness ten-fold greater than in the typical Champlain region of northern New York. The second objection has already been answered by showing that the rocks which pass beneath the Potsdam are really newer strata belonging to the upper part of the division, and contain a characteristic fossil of the Utica slate. As to the third point, it has also been met, so far as regards the Atops and Elliptocephalus, by showing these two genera to belong to the Potsdam formation. If we inquire farther into the Taconic fauna we find that the Stockbridge limestone (the Eolian limestone of Hitchcock), which was placed by Emmons near the base of the Lower Taconic, (while the Olenellus slates are near the summit of the Upper Taconic), is also fossiliferous, and contains, according to the determinations of Professor Hall, species belonging to the genera Euomphalus, Zaphrentis, Stromatopora, Chaetetes and Stictopora.† Such a fauna would lead to the con-

* Geology of Vermont, p. 374.

† Geology of Vermont, 419, and Amer. Jour. Sci., II, xxxiii, 419.

clusion that these limestones instead of being older, were really newer than the Olenellus beds, and that the apparent order of succession was, contrary to the supposition of Emmons, the true one. This conclusion was still farther confirmed by the evidence obtained in 1868 by Mr. Billings, who found in that region a great number of characteristic species of the Levis formation, many of them in beds immediately above or below the white marbles,* which latter, from the recent observations of the Rev. Augustus Wing in the vicinity of Rutland, Vermont, would seem to be among the upper beds of the Potsdam formation. Thus while some of the Taconic fossils belong to the Potsdam and Utica formations, the greater number of them, derived from beds supposed to be low down in the system, are shown to be of the age of the Levis formation. There is, therefore, at present, no evidence of the existence, among the unaltered sedimentary rocks of the western base of the Appalachians in Canada or New England, of any strata more ancient than those of the Champlain division, to which, from their organic remains, the fossiliferous Taconic rocks are shown to belong.

Mr. Billings has, it is true, distinguished provisionally what he has designated an upper and a lower division of the Potsdam, and has referred to the latter the Red sandrock with the Olenellus slates of Vermont, together with beds holding similar fossils at Troy, New York, and along the straits of Bellisle in Labrador and Newfoundland; the upper division of the Potsdam being represented by the basal sandstones of the Ottawa basin and of the Mississippi valley.† In the present state of our knowledge of the local variations in sediments and in their fauna dependent on depth, temperature and ocean currents, Billings, however, conceives that it would be premature to assert that these two types of the Potsdam do not represent synchronous deposits.

The base of the Champlain division, as known in the Potsdam formation of New York, of the Mississippi valley and the Appalachian belt, does not, however, represent the base of the paleozoic series in Europe. The Alum slates in Sweden are divided into two parts, an upper or Olenus zone, and a lower or Conocoryphe zone, as distinguished by Angelin. The latter is characterized by

* Amer. Jour. Sci., II, xlvi, 227.
† Report Geol. of Canada, 1863-66, p. 236.

the genus Paradoxides, which also occupies a lower division in the primordial paleozoic rocks of Bohemia (Barrande's stage C), the greater part of which are regarded as the equivalent of the Olenus zone of Sweden and the Potsdam of North America. The Lingula flags of Wales belong to the same horizon, and it is at their base, in strata once referred to the Lower Lingula flags, that the Paradoxides is met with. These strata, for which Hicks and Salter, in 1865, proposed the name of the Menevian group, are regarded as corresponding to the lower division of the Alum slates, and, like it, contain a fauna not yet recognized in the basal rocks of the New York system. We here approach the debatable land between the Cambrian and the Silurian of the British geologists. The Cambrian, as originally claimed by Sedgwick, included in its upper division the Middle and Upper Lingula flags, with the overlying Tremadoc slates, to the base of the Llandeilo rocks, and may be regarded as equivalent to the Potsdam, Calciferous and Levis formations; while in the Lower Cambrian were embraced the Lower Lingula flags and the Upper and Lower Longmynd rocks, corresponding respectively to the Harlech grits and the Llanberis slates. A portion of the Cambrian has, however, been claimed for the Silurian by Murchison, who draws the dividing line at the top of the Longmynd rocks, leaving the three divisions of the Lingula flags in the Silurian. Lyell, on the contrary, remarks that the Menevian beds, which were, on lithological grounds, made by Sedgwick a part of the Lower Lingula flags, have been shown by Hicks and Salter to be very distinct from these paleontologically; and, while he includes the Menevian in the Lower Cambrian, refers the whole of the Lingula flags to the Upper Cambrian.

Lyell therefore admits the whole of the Cambrian system as originally defined by Sedgwick, and the same classification is now adopted by Linarsson, in Sweden, where in Westrogothia, the Cambrian rocks, (resting unconformably on the crystalline schists to be noticed farther on), are overlaid conformably by the orthoceratite limestones, which are by him regarded as forming the base of the Silurian, and as the equivalent of the Llandeilo rocks of Wales. The total thickness of these lower rocks in Sweden, including the representatives of the Lingula flags, the Menevian beds and an underlying fucoidal (Eophyton) sandstone, is only three hundred feet, while the first two divisions in Wales have a thickness of five to six thousand, and the Harlech grits and Llanberis slates

(including the Welsh roofing-slates beneath) amount to eight thousand feet additional. Recent researches show that these lower rocks in Wales contain an abundant fauna, extending downward some 2800 feet from the Menevian to the very base of strata regarded as the representatives of the Harlech grits. The brachiopoda of the Harlech beds appear identical with those of the Menevian, but new species of *Conocephalites*, *Microdiscus* and *Paradoxides* are met with, besides a new genus, *Plutonia*, allied to the last mentioned. Mr. Hicks, to whom we owe these discoveries,* remarks, that the Menevian gives us, for the present, a well marked paleontological horizon for the summit of the Cambrian, corresponding with the Lower Cambrian as defined by Sedgwick.

The Upper Cambrian in North America would thus include the lower half of the Champlain division from the base of the Potsdam to the summit of the Levis (including perhaps the Chazy), while the Lower Cambrian, (the Cambrian of Murchison and Hicks) is represented by the strata holding Paradoxides in Newfoundland, New Brunswick and eastern Massachusetts. Although no strata marked by these fossils have yet been found in the Appalachians, it is not improbable that such may yet be met with. In May, 1861, I called attention to the fact that beds of quartzose conglomerate at the base of the Potsdam in Hemmingford, near the outlet of Lake Champlain on its western side, contain fragments of green and black slates, "showing the existence of argillaceous slates before the deposition of the Potsdam sandstone."† The more ancient strata, which furnished these slaty fragments to the Potsdam conglomerate, have perhaps been destroyed, or are concealed, but they or their equivalents may yet be discovered in some part of the great Appalachian region. They should not, however, be called Taconic, but receive the prior designation of Cambrian, unless, indeed, it shall appear that the source of these slate fragments was the more argillaceous beds of the still older Huronian schists. Emmons regarded his Taconic system as the equivalent of the Lower Cambrian of Sedgwick, but when in 1842, Murchison announced that the name of Cambrian had ceased to have any zoological significance, being identical with Lower Silurian,‡ Emmons, conceiving, as he tells us, that all

* Geol. Mag., V, 306; and Rep. Brit. Assoc., 1868, p. 69; also Harkness and Hicks in Nature, Proc. Geol. Soc., May 10, 1871.

† Amer. Jour. Sci., II, xxxi, 404.

‡ Proc. Geol. Soc., London, III, 642.

Cambrian rocks were not Silurian, instead of maintaining Sedgwick's name, which with the progress of paleontological study is assuming a great zoological importance, devised the name of Taconic, as synonymous with Lower Cambrian;* although, as we have seen, there is as yet no paleontological evidence to identify any portion of the Taconic strata with the well-defined Lower Cambrian rocks of our eastern shores.

The crystalline infra-Silurian strata, to which the name of the Huronian series has been given by the Geological Survey of Canada, have sometimes been called Cambrian from their resemblance to certain rocks in Anglesea, which have been looked upon as altered Cambrian. The typical Cambrian rocks of Wales, down to their base, are however uncrystalline sediments, and, as pointed out by Dr. Bigsby in 1863,† are not to be confounded with the Huronian, which he regarded as equivalent to the second division of the so-called azoic rocks of Norway, the *Urschiefer* or primitive schists, which in that country rest unconformably on the primitive gneiss (*Urgneiss*), and are in their turn overlaid unconformably by the fossiliferous Cambrian strata. This second or intermediate series in Norway is characterized by eurites, micaceous, chloritic and hornblendic schists, with diorites, steatite and dark colored serpentines, generally associated with chrome; and abounds in ores of copper, nickel and iron. In its mineralogical and lithological characters, the Urschiefer corresponds with what we have designated the second series of crystalline schists. It is, in Norway, divided into a lower or quartzose division, marked by a predominance of quartzites, conglomerates and more massive rocks, and an upper and more schistose division. Macfarlane, who was familiar with the rocks of Norway, after examining both the Huronian of Lake Superior and the crystalline strata of the Green Mountains, had already, in 1862, declared his opinion that both of these were representatives of the Norwegian Urschiefer,‡ thus anticipating, from his comparative studies, the conclusions of Bigsby.

The crystalline rocks of Anglesea and the adjacent part of Caernarvon, which have been described and mapped by the British Geological Survey as altered lowest Cambrian, are directly overlaid by strata of the Llandeilo and Bala divisions, corresponding

* Emmons, Geol. N. District of New York, 162; and Agric. of New York, I, 49.
† Quar. Jour. Geol. Soc., XIX, 36.
‡ Canadian Naturalist, VII, 125.

to the Trenton and Hudson River formations. If we consult Ramsay's report on the region, it will be found that he speaks of them as "probably Cambrian," and states as a reason for that opinion, that they are connected by certain beds of intermediate lithological characters with strata of undoubted Cambrian age.* These, however, as he admits, present great local variations, and, after carefully scanning the whole of the evidence adduced, I am inclined to see in it nothing more than the existence, in this region, of Cambrian strata made up from the ruins from the great mass of pre-Cambrian schists, which are the crystalline rocks of Anglesea. Such a phenomenon is repeated in numerous instances in our North American rocks, and is the true explanation of many supposed examples of passage from crystalline schists to uncrystalline sediments. The Anglesea rocks are a highly inclined and much contorted series of quartzose, micaceous, chloritic and epidotic schists, with diorites and dark colored chromiferous serpentines, all of which, after a careful examination of them in the collections of the Geological Survey of Great Britain, appear to me identical with the rocks of the Green Mountain or Huronian series. A similar view of their age is shared by Phillips and by Sedgwick, in opposition to the opinion of the British survey. The former asserts that the crystalline schists of Anglesea are "below all the Cambrian rocks;"† while Sedgwick expresses the opinion that they are of "a distinct epoch from the other rocks of the district, and evidently older."‡

Associated with the fossiliferous Devonian rocks of the Rhine, is a series of crystalline schists, similar to those just noticed, seen in the Taunus, the Hundsrück and the Ardennes. These, in opposition to Dumont, who regarded them as belonging to an older system, are declared by Römer to have resulted from a subsequent alteration of a portion of the Devonian sediments.§

Turning now to the Highlands of Scotland, we have a similar series of crystalline schists, presenting all the mineralogical characters of those of Norway and of Anglesea, which, according to Murchison and Geikie, are neither of Cambrian nor pre-Cambrian age, but are younger than the fossiliferous limestones of the west-

* Geol. of North Wales, pp. 145, 175.
† Manual of Geology (1855) 89.
‡ Geol. Journal for 1845, 449.
§ Naumann, Geognosie, 2d edition, II, 383.

ern coast (about the horizon of the Levis formation) which seem to pass beneath them. Professor Nicol, on the contrary, maintains that this apparent super-position is due to uplifts, and that these crystalline schists are really older than either Cambrian or Silurian, both of which appear to the west of them as uncrystalline sediments, resting on the Laurentian. He does not, however, confound these crystalline schists of the Scottish Highlands with the Laurentian, from which they differ mineralogically, but regards them as a distinct series.* In the presence of the differences of opinion which have been shown in this controversy, we may be permitted to ask whether, in such a case, stratigraphical evidence alone is to be relied upon. Repeated examples have shown that the most skilful stratigraphists may be misled in studying the structure of a disturbed region where there are no organic remains to guide them, or where unexpected faults and overslides may deceive even the most sagacious. I am convinced that in the study of the crystalline schists, the persistence of certain mineral characters must be relied upon as a guide, and that the language used by Delesse, in 1847, will be found susceptible of a wide application to crystalline strata. "Rocks of the same age have most generally the same chemical and mineralogical composition, and reciprocally, rocks having the same chemical composition and the same minerals, associated in the same manner, are of the same age."†

In this connection the testimony of Professor James Hall is to the point. Speaking of the crystalline schists of the White Mountain series, he says: —

"Every observing student of one or two years experience in the collection of minerals in the New England States, knows well that he may trace a mica-schist of peculiar but varying character from Connecticut, through central Massachusetts, and thence into Vermont and New Hampshire, by the presence of staurolite and some other associated minerals, which mark with the same unerring certainty the geological relations of the rock as the presence of *Pentamerus oblongus*, *P. galeatus*, *Spirifer Niagarensis*, or *S. macropleura*, and their respectively associated fossils do the relations of the several rocks in which these occur."‡

*Quar. Jour. Geol. Soc.; Murchison, XV, 353; Geikie, XVII, 171; Nicol, XVII, 58, XVIII, 443.

† Bull. Soc. Geol. de Fr. (2), IV, 786.

‡ Paleontology of New York, Vol. III, Introduction, page 93.

I am convinced that these crystalline schists of Germany, Anglesea, and the Scotch Highlands, will be found, like those of Norway, to belong to a period anterior to the deposition of the Cambrian sediments, and will correspond with the newer gneissic series of our Appalachian region. There exists, in the Highlands of Scotland, a great volume of fine-grained, thin-bedded mica-schists with andalusite, staurolite and cyanite, which are met with in Argyleshire, Aberdeenshire, Banffshire and the Shetland Isles. Rocks regarded by Harkness as identical with these of the Scottish Highlands also occur in Donegal and Mayo in Ireland. Through the kindness of the Rev. Prof. Haughton of Trinity College, and Mr. Robert H. Scott, then of Dublin, I received some years since, a large collection of the crystalline rocks of Donegal, which I am thus enabled to compare with those of North America, and to assert the existence in the northwest of Ireland, of our second and third series of crystalline schists. The Green Mountain rocks are there exactly represented by the dark colored chromiferous serpentines of Aghadoey, and the steatite, crystalline talc and actinolite of Crohy Head; while the mica-schist of Loch Derg, with white quartz, blue cyanite, staurolite and garnet, all united in the same fragment, cannot be distinguished from specimens found at Cavendish, Vermont, and Windham, Maine. The fine-grained andalusite-schists of Clooney Lough are exactly like those from Mount Washington; while the granitoid mica-slates from several other localities in Donegal are not less clearly of the type of the White Mountain series. Similar micaceous schists, with andalusite (chiastolite), occur on Skiddaw, in Cumberland, England, the relations of which have been clearly defined by Sedgwick, who groups the rocks of Skiddaw into four divisions. The lowest of these, succeeding the granite, is a series of crystalline rocks, not described lithologically, with mineral veins, "having some resemblance to the rocks of Cornwall," and including towards the summit, "chiastolite schists and chiastolite rocks." These are followed in ascending order by two great series of slates and grits, succeeded by a fourth division of schists, sometimes carbonaceous, holding in parts fucoids and graptolites, which are apparently overlaid discordantly by sundry trappean conglomerates and chloritic slates.* The graptolites of the Skiddaw slates

*Synopsis of British Paleozoic Rocks, p. lxxxiv, being an introduction to McCoy's Brit. Pal. Fossils (1855).

are found to be identical with those of the Levis formation,* and it is worthy of notice that although Sedgwick places the mica-schists with andalusite (chiastolite) so far below the graptolitic beds, he elsewhere, in comparing the rocks of North Wales and Cumberland, states that the chloritic and micaceous rocks of Anglesea and Caernarvon are not represented in Cumberland, being distinct from the other rocks of North Wales, and much older.†

In Victoria, Australia, the position of the chiastolite schists, according to Selwyn, is beneath the graptolitic slates. Boblaye, it is true, asserted in 1838 that the chiastolite schists of Les Salles, near Pontivy in Brittany, include *Orthis* and *Calymene*,‡ but when we remember that even experienced observers in the White Mountains for a time mistook for remains of crustacea and brachiopods, certain obscure forms, which they afterwards found not to be organic, and that Dana, in this connection, has called attention to the deceptive resemblance to fossils presented by some imperfectly developed chiastolite crystals in the same region,§ we may well require a verification of Boblaye's observation, especially since we find that more recently D'Archiac and Dalimier agree with De Beaumont and Dufrenoy in placing the chiastolite schists of Brittany at the very base of the transition sediments, marking the summit of the crystalline schists.‖

With regard to the crystalline schists of Lakes Huron and Superior, to which the name of the Huronian system has been given, the observations of all who have studied the region concur in placing them unconformably beneath the sediments which are supposed to represent the base of the New York system, while, on the other hand, they rest unconformably on the Laurentian gneiss, fragments of which are included in the Huronian conglomerates. The gneissic series of the Green Mountains had, however, as we have seen, been, since 1841, regarded by the brothers Rogers, Mather, Hall, Hitchcock, Adams, Logan, myself and others, as of Silurian age. Eaton and Emmons had alone claimed for it a pre-Cambrian age until, in 1862, Macfarlane ventured to unite it with the Huronian system.

* Harkness and Salter, Quar. Jour. Geol. Soc., xix, 135.
† Geol. Journal (1845), IV, 583.
‡ Bull. Soc. Geol. de Fr., X, 227.
§ Amer. Jour. Sci., II, i, 415, v, 116.
‖ Bull. Soc. Geol. de Fr., II, xviii, 661.

and to identify both with the crystalline schists of a similar age in Norway. Later observations in Michigan justify still farther this comparison, for not only the more schistose beds of the Green Mountain series, but even the mica-schists of the third or White Mountain series, with staurolite and garnet, are represented in Michigan, as appears by the recent collections of Major Brooks, of the Geological Survey of Michigan, kindly placed in my hands for examination. He informs me that these latter schists are the highest of the crystalline strata in the northern peninsula.

To the north of Lake Superior, as I have already shown elsewhere, the schists of this third series, which, as early as 1861, I compared to those of the Appalachians, are widely spread; while in Hastings County, forty miles north of Lake Ontario, rocks having the mineralogical and lithological characters both of the second and third series are found resting on the first or Laurentian, the three apparently unconformable, and all in turn overlaid by horizontal Trenton limestone.*

We have shown, that in Pennsylvania, while some of these schists of the second and third series were regarded as altered primal rocks by H. D. Rogers, others, lithologically similar, were referred by him to the older so-called azoic series, which we believe to be their true position. Professor W. B. Rogers has lately informed me that in Virginia the gneissic series having the characters of the Green Mountain rocks, is clearly overlaid unconformably by the lowest primal paleozoic strata of the region. Coming northward, the uncrystalline argillites and sandstones holding Paradoxides at Braintree, Massachusetts,† and St. John, New Brunswick, overlie unconformably crystalline schists of the second series, and in the latter region, in one locality, rocks which are by Bailey and Matthew regarded of Laurentian age. In Newfoundland, in like manner, a great series of crystalline schists, in which Mr. Murray recognizes the Huronian system as first studied and described by him in the west, is unconformably overlaid by a group of sandstones, limestones, and slates holding Paradoxides. The peculiar gneisses and mica-schists of the White Mountain series appear to be developed to a great extent in Newfoundland, which has led me to propose for them the name of the Terranovan system.‡

* Amer. Jour. Sci., II, xxxi, 395, and l, 85.
† Hunt, Proc. Bost. Nat. Hist. Soc., Oct., 19, 1870.
‡ Amer. Jour. Sci., II, l, 87.

From the part which the ruins of these rocks play in the production of succeeding sediments it is not always easy to define the limits between the ancient mica-schists and the Cambrian strata in these northeastern regions. It is not impossible that the two may graduate into each other, as some have supposed, in Newfoundland and Nova Scotia, but until farther light is thrown upon the subject I am disposed to regard the relation between the two as one of derivation rather than of passage.

We have already alluded to the history of the rocks of the White Mountains, formerly looked upon as primary, and by Jackson described as an old granitic and gneissic axis uplifting the more recent Green Mountain rocks. Their manifest differences from the more ancient gneiss of the Adirondacks, and their apparent superposition to the Green Mountain series, then regarded by the Messrs. Rogers as belonging to the Champlain division, led them in 1846 to look upon the White Mountains as altered strata belonging to the Levant division of their classification, corresponding to the Oneida, Medina and Clinton of the New York system. In 1848 Sir William Logan came to a somewhat similar conclusion. Accepting, as we have seen, the view of Emmons that the strata about Quebec included a portion of the Levant division, and regarding the Green Mountain gneisses as the equivalents of these, he was induced to place the White Mountain rocks still higher in the geological series than the Messrs. Rogers had done, and expressed his belief that they might be the altered representatives of the New York system from the base of the Lower Helderberg to the top of the Chemung; in other words, that they were not Middle Silurian, but Upper Silurian and Devonian. This view, adopted and enforced by me,* was farther supported by Lesley in 1860, and has been generally accepted up to this time. In 1870, however, I ventured to question it, and in a published letter addressed to Professor Dana, concluded from a great number of facts that there exists a system of crystalline schists distinct from, and newer than, the Laurentian and Huronian, to which I gave the provisional name of Terranovan, constituting the third or White Mountain series, which appears not only throughout the Appalachians, but westward to the north of Lake Ontario, and around and beyond Lake Superior.† Although I have in common with most

* Geol. Survey of Canada, Report 1847–48, p. 58; also Amer. Jour. Sci., II, ix, 19.
† Amer. Jour. Sci., II, l, 83.

other American geologists, maintained that the crystalline rocks of the Green Mountain and White Mountain series are altered paleozoic sediments, I find, on a careful examination of the evidence, no satisfactory proof of such an age and origin, but an array of facts which appear to me incompatible with the hitherto received view, and lead me to conclude that the whole of our crystalline schists of eastern North America are not only pre-Silurian but pre-Cambrian in age.

In what precedes, I have endeavored to discuss briefly and impartially some of the points in the history of the older rocks, and of the views which during the past thirty years have been entertained as to their age and geological relations, both in America and in Europe. I have said some things which will provoke criticism, and at the same time, I trust, lead to farther study of these rocks, a correct knowledge of which lies at the basis of geological science.

I cannot, however, conclude this part of my subject without referring to the views put forth in 1869 by Professor Hermann Credner of Leipzig, in an essay on the Eozoic or pre-Silurian formations of North America.* With Macfarlane, he refers to the Huronian the gneissic series of the Green Mountains, but includes with it, as part of the Huronian system, the so-called Lower Taconic rocks of Vermont, "with remains of annelids and crinoids." Credner thus falls into the very error against which Emmons warned American geologists, namely, the confounding in one system the ancient crystalline schists with the newer fossiliferous sediments. Resting unconformably on these, he places, first, the Upper Taconic, corresponding, according to him, to a part of the Quebec group, and second, the Potsdam sandstone. In this he has copied, for the most part, Marcou, who, however, groups the whole of these various divisions in the Taconic system, while Credner, rejecting the name, unites a portion of the Taconic of Emmons with the Huronian system, and refers the other portion, together with the Potsdam, to the Silurian. These same views are set forth in a more recent paper, by the same author, on the Alleghany system, which is accompanied with sections and a geologically colored map.† In this, not content with including in the Huronian both the fossiliferous strata of the Levis formation and

* Die Gliederung der Eozoischen Formationsgruppe, u. s. w., pp. 53. Halle, 1869.
† Petermann's Geographische Mittheilungen. 2 Heft, 1871.

the crystalline schists of the Green Mountains, he refers the gneisses and mica-schists of the White Mountains to the same system; while the broad area of similar rocks from their base to the sea at Portland, is regarded as Laurentian. This, on Credner's map, is also made to include, with the exception of the White Mountains themselves, all the rocks of the third or White Mountain series which cover so large a part of New England. Those who have followed the historical sketch already given, can see how widely these notions of Credner differ from those of Emmons, and from all other American geologists, and how much they are at variance with the present state of our knowledge. It is much to be regretted that so good a geologist and lithologist should, from a too superficial study, have fallen into these errors, which can only retard the progress of comparative geognosy, for which he has done so much. In England, again, Credner confounds the Cambrian and Huronian, referring to the latter system the whole of the Longmynd rocks with their characteristic Cambrian fauna, a view which is supported only by the conjectured Cambrian age of the crystalline schists of Anglesea, which are probably pre-Cambrian and veritably Huronian, like the Urschiefer of Scandinavia; which Credner correctly refers to the latter system, as Macfarlane and Bigsby had done before him. He, moreover, recognizes in the similar crystalline schists of Scotland, the Urals, and various parts of Germany, including those of Bavaria and Bohemia, a newer system, overlying the primary or Laurentian gneiss, and corresponding to the Huronian or Green Mountain series of North America, while he suggests a correspondence with similar rocks in Japan, Bengal, and Brazil. In a collection of rocks brought from the latter country by Professor C. F. Hartt, I have found, as elsewhere stated,* what appear to be representatives of the three types of crystalline schists which have been distinguished in eastern North America.

It will be noticed that I have not, in the preceding pages, referred to the Labradorian (Upper Laurentian) system, which is characterized by a great predominance of norites and hyperites. Although occupying a considerable area in the Adirondack region, it is not certainly known in the Appalachian range, and was, therefore, omitted in the discussion. In addition to the facts

* The Nation, Dec. 1, 1870, and Hartt's Geology of Brazil, p. 550.

given by me in 1869,* it may be added that the observations of Mr. Richardson, during that season, on the north side of the Gulf of St. Lawrence, confirm the previous conclusions, and show that the rocks of the Labradorian (or rather Norian) system there repose transgressively, and often at comparatively moderate angles, on the nearly vertical Laurentian gneisses.† We may, I think, in the present state of our knowledge, regard these norites or Norian rocks as portions of a pre-Huronian system.

## II. *The Origin of Crystalline Rocks.*

We now approach the second part of our subject, namely, the genesis of the crystalline schists whose history we have just discussed. The origin of the mineral silicates which make up a great portion of the crystalline rocks of the earth's surface is a question of much geological interest, which has been to a great degree overlooked. The gneisses, mica-schists and argillites of various geological periods do not differ very greatly in chemical constitution from modern mechanical sediments, and are now very generally regarded as resulting from a molecular re-arrangement of similar sediments formed in earlier times by the disintegration of previously existing rocks not very unlike them in composition; the oldest known formations being still composed of crystalline stratified deposits presumed to be of sedimentary origin. Before these the imagination conceives yet earlier rocks, until we reach the surface of unstratified material which the globe may be supposed to have presented before water had begun its work. It is not, however, my present plan to consider this far-off beginning of sedimentary rocks, which I have elsewhere discussed.‡

Apart from the clay and sand-rocks just referred to, whose composition may be said to be essentially quartz and aluminous silicates, chiefly in the forms of feldspars and micas, or the results of their partial decomposition and disintegration, there is another class of crystalline silicated rocks which, though far less important in bulk than the last, is of great and varied interest to the lithologist, the mineralogist, the geologist and chemist. The rocks of this second class may be defined as consisting in great part of the silicates of the protoxyd bases, lime, magnesia and ferrous oxyd,

* On Norites, etc., Amer. Jour. Sci., II, xlviii. 180.
† Geol. Survey of Canada, Report 1866-69, p. 306.
‡ Amer. Jour. Science, II, l, 25.

either alone, or in combination with silicates of alumina and alkalies. They include the following as their chief constituent mineral species:—pyroxene, hornblende, olivine, serpentine, talc, chlorite, epidote, garnet and triclinic feldspars such as labradorite. The great types of this second class are not less well defined than the first, and consist of pyroxenic and hornblendic rocks, passing into diorites, diabases, ophiolites and talcose, chloritic and epidotic rocks. Intermediate varieties resulting from the association of the minerals of this class with those of the first, and also with the materials of non-silicated rocks, such as limestones and dolomites, show an occasional blending of the conditions under which these various types of rocks were formed.

The distinctions just drawn between the two great divisions of silicated rocks, are not confined to stratified deposits, but are equally well marked in eruptive and unstratified masses, among which the first type is represented by trachytes and granites, and the second, by dolerites and diorites. This fundamental difference between acid and basic rocks, as the two classes are called, finds its expression in the theories of Phillips, Durocher and Bunsen, who have deduced all silicated rocks from two supposed layers of molten matter within the earth's crust, consisting respectively of acid and basic mixtures; the trachytic and pyroxenic magmas of Bunsen. From these, by a process of partial crystallization and eliquation, or by commingling in various proportions, those eruptive rocks which depart more or less from the normal types, are supposed by the theorists of this school to be generated.* The doctrine that these eruptive rocks are not derived directly from a hitherto uncongealed nucleus, but are softened and crystallized sediments, in fact that the whole of the rocks at present known to us have at one time been aqueous deposits, has, however, found its advocates. In support of this view, I have endeavored to show that the natural result of forces constantly in operation, tends to resolve the various igneous rocks into two classes of sediments, in which the two types are, to a great extent, preserved. The mechanical and chemical agencies which transform the crystalline rocks into sediments, separate these more or less completely into coarse, sandy, permeable beds on the one hand, and fine clayey impervious muds on the other. The action of infiltrating atmospheric waters on the first and more silicious strata, removes from them lime, magnesia, iron-oxyd and

* Hunt on Some Points of Chemical Geology, Quar. Jour. Geol. Soc., XV, 489.

soda, leaving behind silica, alumina and potash — the elements of granitic, gneissic and trachytic rocks. The finer and more aluminous sediments, including the ruins of the soft and easily abraded silicates of the pyroxene group, resisting the penetration of the water, will, on the contrary, retain their alkalies, lime, magnesia and iron, and thus will have the composition of the more basic rocks. *

A little consideration will, however, show that this process, although doubtless a true cause of differences in the composition of sedimentary rocks, is not the only one, and is inadequate to explain the production of many of the varieties of stratified silicated rocks. Such are serpentine, steatite, hornblende, diallage, chlorite, pinite and labradorite, all of which mineral species form rock-masses by themselves, frequently almost without admixture. No geological student will now question that all of these rocks occur as members of stratified formations. Moreover, the manner in which serpentines are found interstratified with steatite, chlorite, argillite, diorite, hornblende and feldspar rocks, and these, in their turn, with quartzites and orthoclase rocks, is such as to forbid the notion that these various materials have been deposited, with their present composition, as mechanical sediments from the ruins of preëxisting rocks; a hypothesis as untenable as that ancient one which supposed them to be the direct results of plutonic action.

There are, however, two other hypotheses which have been proposed to explain the origin of these various silicated rocks, and especially of the less abundant, and, as it were, exceptional species just mentioned. The first of these supposes that the minerals of which they are composed, have resulted from an alteration of previously existing minerals, often very unlike in composition to the present, by the taking away of certain elements and the addition of certain others. This is the theory of metamorphism by pseudomorphic changes, as they are called, and is the one taught by the now reigning school of chemical geologists, of which the learned and laborious Bischof, whose recent death science deplores, may be regarded as the great exponent. The second hypothesis supposes that the elements of these various rocks were originally deposited as, for the most part, chemically formed sediments, or precipitates; and that the subsequent changes have been simply

* Quar. Jour. Geol. Soc., xv, 489; also, Amer. Jour. Sci., II, xxx, 151.

molecular, or, at most, confined in certain cases to reactions between the mingled elements of the sediments, with the elimination of water and carbonic acid. It is proposed to consider briefly, these two opposite theories, which seek to explain the origin of the rocks in question respectively by pseudomorphic changes in preëxisting crystalline rocks, and by the crystallization of aqueous sediments, for the most part chemically formed precipitates.

Mineral pseudomorphism, that is to say, the assumption by one mineral substance of the crystalline form of another, may arise in several ways. First of these is the filling up of a mould left by the solution or decomposition of an imbedded crystal, a process which sometimes takes place in mineral veins, where the processes of solution and deposition can be freely carried on. Allied to this, is the mineralization of organic remains, where carbonate of lime or silica, for example, fills the pores of wood. When subsequent decay removes the woody tissue, the vacant spaces may, in their turn, be filled by the same or another species. * In the second place, we may consider pseudomorphs from alteration, which are the result of a gradual change in the composition of a mineral species. This process is exemplified in the conversion of feldspar into kaolin by the loss of its alkali and a portion of silica, and the fixation of water, or in the change of chalybite into limonite by the loss of carbonic acid and the absorption of water and oxygen.

The doctrine of pseudomorphism by alteration as taught by Gustaf Rose, Haidinger, Blum, Volger, Rammelsberg, Dana, Bischof, and many others, leads them, however, to admit still greater and more remarkable changes than these, and to maintain the possibility of converting almost any silicate into any other. Thus, by referring to the pages of Bischof's Lehrbuch der Geognosie, it will be found that serpentine is said to exist as a pseudomorph after augite, hornblende, olivine, chondrodite, garnet, mica, and probably also after labradorite, and even orthoclase. Serpentine rock or ophiolite is supposed to have resulted, in different cases, from the alteration of hornblende-rock, diorite, granulite and even granite. Not only silicates of protoxyds and aluminous silicates are conceived to be capable of this transformation, but probably also quartz itself; at least, Blum asserts that meerschaum, a closely re-

* Hunt on the Silicification of Fossils, Canadian Naturalist, new series, I, 46.

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* Hunt on the Silicification of Fossils, Canadian Naturalist, new series, I, 46.

lated silicate of magnesia, which sometimes accompanies serpentine, results from the alteration of flint; while according to Rose, serpentine may even be produced from dolomite, which we are told is itself produced by the alteration of limestone. But this is not all, — feldspar may replace carbonate of lime, and carbonate of lime, feldspar, so that, according to Volger, some gneissoid limestones are probably formed from gneiss by the substitution of calcite for orthoclase. In this way, we are led from gneiss or granite to limestone, from limestone to dolomite, and from dolomite to serpentine, or more directly from granite, granulite or diorite to serpentine at once, without passing through the intermediate stages of limestone and dolomite, till we are ready to exclaim in the words of Goethe: —

> "Mich ängstigt das Verfängliche
> Im widrigen Geschwätz,
> Wo Nichts verharret, Alles flieht,
> Wo schon verschwunden was man sieht."*

which we may thus translate: — "I am vexed with the sophistry in their contrary jargon, where nothing endures, but all is fugitive, and where what we see has already passed away."

By far the greater number of cases on which this general theory of pseudomorphism by a slow process of alteration in minerals, has been based are, as I shall endeavor to show, examples of the phenomenon of mineral envelopment, so well studied by Delesse in his essay on Pseudomorphs,† and may be considered under two heads: — first, that of symmetrical envelopment, in which one mineral species is so enclosed within the other that the two appear to form a single crystalline individual. Examples of this are seen when prisms of cyanite are surrounded by staurolite, or staurolite crystals completely enveloped in those of cyanite, the vertical axes of the two prisms corresponding. Similar cases are seen in the enclosure of a prism of red in an envelope of green tourmaline, of allanite in epidote, and of various minerals of the pyroxene group in one another. The occurrence of muscovite in lepidolite, and of margarodite in lepidomelane, or the inverse, are well-known examples, and, according to Scheerer, the crystallization of serpentine around a nucleus of olivine is a similar case. This phenomenon of symmetrical envelopment, as remarked by Delesse, shows

* Chinesisch-Deutsche Jahres und Tages Zeiten, xi.
† Annales des Mines, V, xvi, 317-392.

itself with species which are generally isomorphous or homœomorphous, and of related chemical composition. Allied to this is the repeated alternation of crystalline laminæ of related species, as in perthite, the crystalline cleavable masses of which consist of thin, alternating layers of orthoclase and albite.

Very unlike to the above are those cases of envelopment in which no relations of crystalline symmetry nor of similar chemical constitution can be traced. Examples of this kind are seen in garnet crystals, the walls of which are shells, sometimes no thicker than paper, enclosing in different cases, crystalline carbonate of lime, epidote, chlorite or quartz. In like manner, crystalline shells of leucite enclose feldspar, hollow prisms of tourmaline are filled with crystals of mica or with hydrous peroxyd of iron, and crystals of beryl with a granular mixture of orthoclase and quartz, holding small crystals of garnet and tourmaline, a composition identical with the enclosing granitic veinstone.* Similar shells of galenite and of zircon, having the external forms of these species, are also found filled with calcite. In many of these cases the process seems to have been first the formation of a hollow mould or skeleton-crystal (a phenomenon sometimes observed in salts crystallizing from solutions), the cavity being subsequently filled with other matters. Such a process is conceivable in free crystals found in veins, as for example, galenite, zircon, tourmaline, beryl and some examples of garnet, but is not so intelligible in the case of those garnets imbedded in mica-schist, studied by Delesse, which enclosed within their crystalline shells irregular masses of white quartz, with some little admixture of garnet. Delesse conceives these and similar cases to be produced by a process analogous to that seen in the crystallization of calcite in the Fontainebleau sandstone; where the quartz grains, mechanically enclosed in well-defined rhombohedral crystals, equal, according to him, sixty-five per cent., of the mass. Very similar to these are the crystalloids with the form of orthoclase, which sometimes consist in large part of a granular mixture of quartz, mica and orthoclase, with a little cassiterite, and in other cases, contain two-thirds their weight of the latter mineral, with an admixture of orthoclase and quartz. Crystals with the form of scapolite, but made up, in a great part, of mica, seem to be like cases of envelopment, in which a small proportion of one substance in the act of crystallization, compels in-

* Report Geol. Survey of Canada, 1866, page 189.

to its own crystalline form a large portion of some foreign material, which may even so mask the crystallizing element that this becomes overlooked, as of secondary importance. The substance which, under the name of houghite, has been described as an altered spinel, is found by analysis to be an admixture of völlknerite with a variable proportion of spinel, which, in some specimens, does not exceed eight per cent., but to which, nevertheless, these crystalloids appear to owe their more or less complete octohedral form.*

The above characteristic examples of symmetrical and asymmetrical envelopment are cited from a great number of others which might have been mentioned. Very many of these are by the pseudomorphists regarded as results of partial alteration. Thus, in the case of associated crystals of andalusite and cyanite, Bischof does not hesitate to maintain the derivation of andalusite from the latter species by an elimination of quartz; more than this, as the andalusite in question occurs in a granite-like rock, he suggests that itself is a product of the alteration of orthoclase. In like manner the mica, which in some cases coats tourmaline, and in others, fills hollow prisms of this mineral, is supposed to result from a subsequent alteration of crystallized tourmaline. So in the case of shells of leucite filled with feldspar, or of garnet enclosing epidote, or chlorite, or quartz, a similar transformation of the interior is supposed to have been mysteriously effected, while the external portion of the crystal remains intact. Again the aggregates of tinstone, quartz and orthoclase having the form of the latter, are, by Bischof and his school, looked upon as results of a partial alteration of previously formed orthoclase crystals. It needed only to extend this view to the crystals of calcite enclosing sand-grains, and regard these as the result of a partial alteration of the carbonate of lime. There is absolutely no proof that these hard crystalline substances can undergo the changes supposed, or can be absorbed and modified like the tissues of a living organism. It may, moreover, be confidently affirmed that the obvious facts of envelopment are adequate to explain all the cases of association upon which this hypothesis of pseudomorphism by alteration, has been based. Why the change should extend to some parts of a crystal and not to others, why in some cases the exterior of the crystal is altered, while in others the centre alone

* Report Geol. Survey of Canada, 1866, pp. 189, 213. Amer. Jour. Sci., III, i, 188.

is removed and replaced by a different material, are questions which the advocates of this fanciful hypothesis have not explained. As taught by Blum and Bischof, however, these views of the alteration of mineral species have not only been generally accepted but have formed the basis of the generally received theory of rock-metamorphism.

Protests against the views of this school have, however, not been wanting. Scheerer, in 1846, in his researches in Polymeric Isomorphism,* attempted to show that iolite and aspasiolite, a hydrous species which had been looked upon as resulting from its alteration, were isomorphous species crystallizing together, and, in like manner, that the association of olivine and serpentine in the same crystal, at Snarum in Norway, was a case of envelopment of two isomorphous species. In both of these instances he maintained the existence of isomorphous relations between silicates in which 3HO replaced MgO. He hence rejected the view of Gustaf Rose that these serpentine crystals were results of the alteration of olivine, and supported his own by reasons drawn from the conditions in which the crystals occur. In 1853 I took up this question and endeavored to show that these cases of isomorphism described by Scheerer, entered into a more general law of isomorphism pointed out by me among homologous compounds differing in their formulas by $nM_2O_2$ (M = hydrogen or a metal). I insisted, moreover, on its bearing upon the received views of the alteration of minerals, and remarked, "The generally admitted notions of pseudomorphism seem to have originated in a too exclusive plutonism, and require such varied hypotheses to explain the different cases, that we are led to seek for some more simple explanation and to find it, in many instances, in the association and crystallizing together of homologous and isomorphous species."† Subsequently, in 1860, I combated the view of Bischof, adopted by Dana, that "regional metamorphism is pseudomorphism on a grand scale," in the following terms:—

"The ingenious speculations of Bischof and others, on the possible alteration of mineral species by the action of various saline and alkaline solutions, may pass for what they are worth, although we are satisfied that by far the greater part of the so-called cases of pseudomorphism in silicates are purely imaginary, and, when

* Pogg. Annal., lxviii, 319.
† Pogg. Annal., lxviii. 19.

real, are but local and accidental phenomena. Bischof's notion of the pseudomorphism of silicates like feldspars and pyroxenes, presupposes the existence of crystalline rocks, whose generation this neptunist never attempts to explain, but takes his starting-point from a plutonic basis."

I then asserted that the problem to be solved in regional metamorphism is the conversion of sedimentary strata, "derived by chemical and mechanical agencies from the ocean-waters and pre-existing crystalline rocks into aggregations of crystalline silicates. These metamorphic rocks, once formed, are liable to alteration only by local and superficial agencies, and are not, like the tissues of a living organism, subject to incessant transformations, the pseudomorphism of Bischof."*

I had not, at that time, seen the essay by Delesse on Pseudomorphs already referred to, published in 1859, in which he maintained views similar to those set forth by me in 1853 and 1860, declaring that much of what had been regarded as pseudomorphism had no other basis than the observed associations of minerals, and that often "the so-called metamorphism finds its natural explanation in envelopment." These views he ably and ingeniously defended by a careful discussion of the whole range of facts belonging to the history of the subject.

My own expression of opinion on this question, in 1853, had been privately criticised, and I had been charged with a want of comprehension of the question. It was, therefore, with no small pleasure, that I not only saw my views so ably supported by Delesse, but read the language of Carl Friedrich Naumann, who in 1861 wrote to Delesse as follows, referring to his essay just noticed:—

"You have rendered a veritable service to science in restricting pseudomorphs to their true limits, and separating what had been erroneously united to them. As you have remarked, envelopments have, for the most part, nothing in common with pseudomorphs, and it is inconceivable that they have been united by so many mineralogists and geologists. It appears to me, moreover, that they commit an analogous error, when they regard gneisses, amphibolites, etc., as being, all of them, the results of metamorphic epigenesis, and not original rocks. It is precisely because pseudomorphism has been so often confounded with metamorphism that this error has found acceptance. I only admit a pseudomorph

* Amer. Jour. Sci., II, xxx, 135.

where there is some crystal the form of which has been preserved. There are very many metamorphic substances which are, in no sense of the word, pseudomorphs. Had the name of *crystalloid* been chosen, instead of pseudomorph, this confusion would certainly have never found its way into the science. I think, with you, that the envelopment of two minerals is most generally explained by a *contemporaneous* and *original* crystallization. Secondary envelopments, however, exist, and such may be called pseudomorphs or crystalloids, if they reproduce exactly the form of the crystal enveloped, whether this last still remains, or has entirely disappeared."*

It is unnecessary to remark that the view of Delesse and Naumann, viz.: that the so-called cases of pseudomorphism, on which the theory of metamorphism by alteration has been built, are, for the most part, examples of association and envelopment, and the result of a contemporaneous and original crystallization,—is identical with the view suggested by Scheerer, and generalized by myself long before, when, in 1853, I sought to explain the phenomena in question by "the association and crystallizing together of homologous and isomorphous species."

Later, in 1862, I wrote as follows:—

"Pseudomorphism, which is the change of one mineral species into another, by the introduction or the elimination of some element or elements, presupposes metamorphism (*i. e.*, metamorphic or crystalline rocks), since only definite mineral species can be the subjects of this process. To confound metamorphism with pseudomorphism, as Bischof, and others after him have done, is therefore an error. It may be farther remarked, that, although certain pseudomorphic changes may take place in some mineral species, in veins and near the surface, the alteration of great masses of silicated rocks by such a process is as yet an unproved hypothesis."†

Thus this unproved theory of pseudomorphism, as taught by Bischof, does not, even if admitted to its fullest extent, advance us a single step towards a solution of the problem of the origin of the various silicates, which, singly or intermingled, make up beds in the crystalline schists. Granting, for the sake of argument, that serpentine results from the alteration of olivine or labradorite, and steatite or chlorite from hornblende, the origin of

* Bull. Soc. Geol. de France, II, xviii, 678.

† Descriptive Catalogue, Crystalline Rocks of Canada, p. 80, London Exhibition, 1862; also, Dublin Quar. Journal, July 1863, and Amer. Jour. Sci., II, xxxvi, 218.

these anhydrous silicates, which are the subjects of the supposed change, is still unaccounted for. The explanation of this short-sightedness is not far to seek; as already remarked, Bischof, although a professed neptunist, starts from a plutonic basis. When the epigenic origin of serpentine and its related rocks was first taught, these were regarded as eruptive and unstratified, and it was easy to imagine intruded masses of dioritic and feldspathic rocks, which had become the subjects of alteration. As, however, the progress of careful investigation in the field has shown the stratified character of these serpentines, diallage-rocks, steatites, etc., and their intercalation among limestones, argillites, quartzites, gneisses, and mica-schists, and even among feldspathic and hornblendic strata, we are forced to reject, with Naumann, the notion of their epigenic derivation, and to regard them as original rocks.

This view brings us face to face with the problem of metamorphism as defined by me in 1860* (*ante*, page 46). We must either admit that these crystalline schists were created as we find them, or suppose that they were once sands, clays, marls, etc.; in a word, sediments of chemical and mechanical origin, which by a subsequent process have been consolidated and crystallized. Whence, then, come these silicates of magnesia, lime, and iron, which are the sources of serpentine, hornblende, steatite, chlorite, etc.? This is the question which I proposed in that same year, when, after discussing the results of my examinations of the tertiary rocks near Paris, containing layers of a hydrous silicate of magnesia related to talc in composition, among unaltered limestones and clays, I remarked that it is evident "such silicates may be formed in basins at the earth's surface, by reactions between magnesian solutions and dissolved silica;" and, after some farther discussion, said "farther inquiries in this direction may show to what extent certain rocks composed of calcareous and magnesian silicates may be directly formed in the moist way."† Subsequently, in a paper on "The Origin of some Magnesian and Aluminous Rocks," printed in the "Canadian Naturalist" for June, 1860,‡ I repeated these considerations, referring to the well-known fact that silicates of lime, magnesia

*Amer. Jour. Sci., II, xxx, 135.
† Ibid., II, xxix, 284; also II, xl, 49.
‡ Ibid., II, xxxii, 286.

and iron-oxyd are deposited during the evaporation of natural waters, including those of alkaline springs and of the Ottawa River. Having described the mode of occurrence of the magnesian silicate, sepiolite, in the Paris basin, and the related quincite, containing some iron-oxyd and disseminated in limestone, I suggested that while steatite has been derived from a compound like sepiolite, the source of serpentine was to be sought in another silicate richer in magnesia; and, moreover, that chlorite, unless the result of a subsequent reaction between clay and carbonate of magnesia, was directly formed by a process analogous to that which (according to Scheerer) has, in recent times, caused the deposition from waters of neolite, a hydrous alumino-magnesian silicate approaching to chlorite in composition,* "the type of a reaction which formerly generated beds of chlorite in the same way as those of sepiolite or talc." Delesse, subsequently, in 1861, in his essay on Rock-Metamorphism insisted upon the sepiolites or so-called magnesian marls, as probably the source of steatite, and suggested the derivation of serpentine, chlorite, and other related minerals of the crystalline schists, from deposits approaching these marls in composition.† He recalled, also, the occurrence of chromic oxyd, a frequent accompaniment of these magnesian minerals, in the hydrated iron ores of the same geological horizon with the magnesian marls in France. Delesse did not, however, attempt to account for the origin of these deposits of magnesian marls, in explanation of which I afterwards verified Bischof's observations on the sparing solubility of silicate of magnesia, and showed that silicate of soda, or even artificial hydrated silicate of lime, when added to waters containing magnesian chlorid or sulphate, gives rise, by double decomposition, to a very insoluble magnesian silicate.‡

To explain the generation of silicates like labradorite, scapolite, garnet, and saussurite, I suggested that double aluminous silicates allied to the zeolites might have been formed, and subsequently rendered anhydrous. The production of zeolitic minerals observed by Daubrée at Plombières and Luxeuil by the action of a silicated alkaline water on the masonry of ancient Roman baths, was appealed to by way of illustration. It had there been shown

* Pogg. Annal., lxxi, 288.

† Etudes sur le Metamorphisme, quarto, pp. 91. Paris, 1861.

‡ Amer. Jour. Sci., II, xl, 49.

by Daubrée that the elements of the zeolites had been derived in part from the waters, and in part from the mortar and even the clay of the bricks, which had been attacked, and had entered into combination with the soluble matters of the water to form chabazite. I, however, at the same time pointed out another source of silicated minerals, upon which I had insisted since 1857, viz.: the reaction between silicious or argillaceous matters and earthy carbonates in the presence of alkaline solutions. Numerous experiments showed that when solutions of an alkaline carbonate were heated with a mixture of silica and carbonate of magnesia, the alkaline silicate formed acted upon the latter, yielding a silicate of magnesia, and regenerating the alkaline carbonate; which, without entering into permanent combination, was the medium through which the union of the silica and the magnesia was effected. In this way I endeavored to explain the alteration, in the vicinity of a great intrusive mass of dolerite, of a gray Silurian limestone, which contained, besides a little carbonate of magnesia and iron-oxyd, a portion of very silicious matter, consisting apparently of comminuted orthoclase and quartz. In place of this, there had been developed in the limestone, near its contact with the dolerite, an amorphous greenish basic silicate, which had seemingly resulted from the union of the silica and alumina with the iron-oxyd, the magnesia and a portion of lime. By the crystallization of the products thus generated it was conceived that minerals like hornblende, garnet and epidote might be developed in earthy sediments, and many cases of local alteration explained. Inasmuch as the reaction described required the intervention of alkaline solutions, rocks from which these were excluded would escape change, although the other conditions might not be wanting. The natural associations of minerals, moreover, led me to suggest that alkaline solutions might favor the crystallization of aluminous silicates, and thus convert mechanical sediments into gneisses and mica-schists. The ingenious experiments of Daubrée on the part which solutions of alkaline silicates, at elevated temperatures, may play in the formation of crystallized minerals, such as feldspar and pyroxene, were posterior to my early publications on the subject, and fully justified the importance which, early in 1857, I attributed to the intervention of alkaline silicates in the formation of crystalline silicated minerals.*

*Proc. Royal Soc., May 7, 1857. Amer. Jour. Sci., II, xxiii, 438, and xxv, 289 and 435.

While, however, there is good reason to believe that solutions of alkaline silicates or carbonates have been efficient agents in the crystallization and molecular re-arrangement of ancient sediments, and have also played an important part in that local alteration of sedimentary strata which is often observed in the vicinity of intrusive rocks, it is clear to me that the agency of these solutions is less universal than once supposed by Daubrée and myself, and will not account for the formation of various silicated rocks found among crystalline schists, such as serpentine, hornblende, steatite and chlorite. When I commenced the study of these crystalline strata I was led, in accordance with the almost universally received opinion of geologists, to regard them as resulting from a subsequent alteration of paleozoic sediments, which, according to different authorities, were of Cambrian, Silurian or Devonian age. Thus in the Appalachian region, as we have already seen, they have, on supposed stratigraphical evidence, been successively placed at the base, at the summit, and in the middle of the Lower Silurian or Champlain division of the New York system. A careful chemical examination among the unaltered paleozoic sediments, which in Canada were looked upon as the stratigraphical equivalents of the bands of magnesian silicates in these crystalline schists, showed me, however, no magnesian rocks except certain silicious and ferruginous dolomites. From a consideration of reactions which I had observed to take place in such admixtures in presence of heated alkaline solutions, and from the composition of the basic silicates which I had found to be formed in silicious limestones near their contact with eruptive rocks, I was led to suppose that similar actions, on a grand scale, might transform these silicious dolomites of the unaltered strata into crystalline magnesian silicates.

Farther researches, however, convinced me that this view was inapplicable to the crystalline schists of the Appalachians, since, apart from the geognostical considerations set forth in the previous part of this paper, I found that these same crystalline strata hold beds of quartzose dolomite and magnesian carbonate, associated in such intimate relations with beds of serpentine, diallage and steatite, as to forbid the notion that these silicates could have been generated by any transformations or chemical re-arrangement of mixtures like the accompanying beds of quartzose magnesian carbonates. Hence it was that already, in 1860, as shown above, I

announced my conclusion that serpentine, chlorite and steatite had been derived from silicates like sepiolite, directly formed in waters at the earth's surface, and that the crystalline schists had resulted from the consolidation of previously formed sediments, partly chemical and partly mechanical in their origin. The latter being chiefly silico-aluminous, took, in part, the forms of gneiss and mica-schists, while from the more argillaceous strata, poorer in alkali, much of the aluminous silicate crystallized as andalusite, staurolite, cyanite and garnet. These views were reiterated in 1863,* and farther in 1864, in the following language, as regards the chemically-formed sediments: "steatite, serpentine, pyroxene, hornblende, and in many cases, garnet, epidote and other silicated minerals are formed by a crystallization and molecular re-arrangement of silicates generated by chemical processes in waters at the earth's surface."† Their alteration and crystallization was compared to that of the mechanically formed feldspathic, silicious and argillaceous sediments just mentioned.

The direct formation of the crystalline schists from an aqueous magma is a notion which belongs to an early period in geological theory. Delabeche in 1834‡ conceived that they were thrown down as chemical deposits from the waters of the heated ocean, after its reaction on the crust of the cooling globe, and before the appearance of organic life. This view was revived by Daubrée in 1860. Having sought to explain the alteration of paleozoic strata of mechanical origin, by the action of heated waters, he proceeds to discuss the origin of the still more ancient crystalline schists. The first precipitated waters, according to him, acting on the anhydrous silicates of the earth's crust, at a very elevated temperature, and at a great pressure, which he estimated at two hundred and fifty atmospheres, formed a magma, from which, as it cooled, were successively deposited the various strata of the crystalline schists.§ This hypothesis, violating, as it does, all the notions which sound theory teaches with regard to the chemistry of a cooling globe, has, moreover, to encounter grave geognostical difficulties. The pre-Silurian crystalline rocks belong to two or more distinct systems of different ages, succeeding each other in discordant strat-

*Geol. of Canada, pp. 577—581.
†Amer. Jour. Sci., II, xxxvii, 266, and xxxviii, 183.
‡Researches in Theoretical Geology, pp. 297–300.
§Etudes et expériences synthétiques sur le Metamorphisme, pp. 119-121.

ification. The whole history of these rocks, moreover, shows that their various alternating strata were deposited, not as precipitates from a seething solution, but under conditions of sedimentation very like those of more recent times. In the oldest known of them, the Laurentian system, great limestone formations are interstratified with gneisses, quartzites and even with conglomerates. All analogy, moreover, leads us to conclude that even at this early period, life existed at the surface of the planet. Great accumulations of iron-oxyd, beds of metallic sulphids and of graphite, exist in these oldest strata, and we know of no other agency than that of organic matter, capable of generating these products.

Bischof had already arrived at the conclusion, which in the present state of our knowledge seems inevitable, that "all the carbon yet known to occur in a free state, can only be regarded as a product of the decomposition of carbonic acid, and as derived from the vegetable kingdom." He farther adds, "living plants decompose carbonic acid; dead organic matters decompose sulphates, so that, like carbon, sulphur appears to owe its existence in a free state to the organic kingdom."* As a decomposition (deoxidation) of sulphates is necessary to the production of metallic sulphids, the presence of the latter, not less than that of free sulphur and free carbon, depends on organic bodies; the part which these play in reducing and rendering soluble the peroxyd of iron, and in the production of iron ores is, moreover, well known. It was, therefore, that, after a careful study of these ancient rocks, I declared in May, 1858, that a great mass of evidence "points to the existence of organic life, even during the Laurentian or so-called azoic period."†

This prediction was soon verified in the discovery of the *Eozoön Canadense*, of Dawson, the organic character of which is now admitted by all zoologists and geologists of authority. But with this discovery, appeared another fact, which afforded a signal verification of my theory as to the origin and mode of deposition of serpentine and pyroxene. The microscopic and chemical researches of Dawson and myself showed that the calcareous skeleton of this foraminiferal organism was filled with the one or the other of these silicates in such a manner as to make it evident that

* Bischof, Lehrbuch, 1st. ed., II, 95. English ed., I, 252, 344.
† Amer. Jour. Science, II, xxv, 436.

they had replaced the sarcode of the animal, precisely as glauconite and similar silicates have, from the Silurian times to the present, filled and injected more recent foraminiferal skeletons. I recalled, in connection with this discovery the observations of Ehrenberg, Mantell and Bailey, and the more recent ones of Pourtales, to the effect that glauconite or some similar substance occasionally fills the spines of Echini, the cavities of corals and millepores, the canals in the shells of Balanus, and even forms casts of the holes made by burrowing sponges (Clionia) and worms. The significance of these facts was farther illustrated by showing that the so-called glauconites differ considerably in composition, some of them containing more or less alumina or magnesia, and one from the tertiary limestones near Paris being, according to Berthier, a true serpentine.*

These facts in the history of Eozoön, were first made known by me in May, 1864, in the American Journal of Science, and subsequently more in detail, February, 1865, in a communication to the Geological Society of London.† They were speedily verified by Dr. Gümbel, who was then engaged in the study of the ancient crystalline schists of Bavaria, and soon recognized the existence, in the limestones of the old Hercynian gneiss, of the characteristic *Eozoön Canadense*, injected with silicates in a manner precisely similar to that observed by Dawson and myself.‡ Later, in 1869, Robert Hoffmann described the results of a minute chemical examination of the Eozoön from Raspenau, in Bohemia, confirming the previous observations in Canada and Bavaria. He showed that the calcareous shell of the Eozoön, examined by him, had been injected by a peculiar silicate, which may be described as related in composition both to glauconite and to chlorite. The masses of Eozoön he found to be enclosed and wrapped around by thin alternating layers of a green magnesian silicate allied to picrosmine, and a brown non-magnesian mineral, which proved to be a hydrous silicate of alumina, ferrous oxyd and alkalies, related to fahlunite, or more nearly to jollyte in composition.§

Still more recently, in the course of the present year, Dr. Dawson detected a mineral insoluble in acids, injecting the pores of

* Amer. Jour. Sci., II, xl, 360, Report Geol. Survey Canada, 1866, p. 231, and Quar. Geol. Jour., XXI, 71.

† Amer. Jour. Sci., II, xxxvii, 431. Quar. Geol. Jour., XXI, 67.

‡ Proc. Royal Bavar. Acad. for 1866, and Can. Naturalist, new series III, 81.

§ Jour. fur. Prakt. Chem., May, 1869, and Amer. Jour. Sci., III, i, 378.

crinoidal stems and plates in a paleozoic limestone from New Brunswick, which is made up of organic remains. This silicate which, in decalcified specimens, shows in a beautiful manner the intimate structure of these ancient crinoids, I have found by analysis to be a hydrous silicate of alumina and ferrous oxyd, with magnesia and alkalies, closely related to fahlunite and to jollyte.* The microscopic examinations of Dr. Dawson show that this silicate injected the pores of the crinoidal remains and some of the interstices of the associated shell-fragments, before the introduction of the calcite which cements the mass. I have since found a silicate almost identical with this, occurring under similar conditions in an Upper Silurian limestone said to be from Llangedoc in Wales.

Gümbel, meanwhile, in the essay on the Laurentian rocks of Bavaria, in 1866, already referred to, fully recognized the truth of the views which I had put forward, both with regard to mineralogy of Eozoön and to the origin of the crystalline schists. His results are still farther detailed in his *Geognost. Beschreibung des östbayerisches Grenzegebirges*, 1868, p. 833. Credner, moreover, as he tells us,† had already from his mineralogical and lithological studies, been led to admit my views as to the original formation of serpentine, pyroxene and similar silicates (which he cites from my paper of 1865, above referred to‡), when he found that Gümbel had arrived at similar conclusions. The views of the latter, as cited by Credner from the work just referred to, are in substance as follows: — The crystalline schists, with their interstratified layers, have all the characters of altered sedimentary deposits, and from their mode of occurrence cannot be of igneous origin, nor the result of epigenic action. The originally formed sediments are conceived to have been amorphous, and under moderate heat and pressure to have arranged themselves, and crystallized, generating various mineral species in their midst by a change, which, to distinguish it from metamorphism by an epigenic process, Gümbel happily designates *diagenesis*.

It is unnecessary to remark, that these views, the conclusions from the recent studies of Gümbel in Germany and Credner in North America, are identical with those put forth by me in 1860.

* Amer. Jour. Sci., III, i, 379.

† Hermann Credner; die Gleiderung der Eozoischen Formationsgruppe Nord Amerikas. Halle 1869. ‡ That in the Quar. Geol. Jour., XXI, 67.

At the early periods in which the materials of the ancient crystalline schists were accumulated, it cannot be doubted that the chemical processes which generated silicates were much more active than in more recent times. The heat of the earth's crust was probably then far greater than at present, while a high temperature prevailed at comparatively small depths, and thermal waters abounded. A denser atmosphere, charged with carbonic acid gas, must also have contributed to maintain, at the earth's surface, a greater degree of heat, though one not incompatible with the existence of organic life.* These conditions must have favored many chemical processes, which, in later times, have nearly ceased to operate. Hence we find that subsequently to the eozoic times, silicated rocks of clearly marked chemical origin are comparatively rare. In the mechanical sediments of later periods certain crystalline minerals may be developed by a process of molecular re-arrangement — diagenesis. These are, in the feldspathic and aluminous sediments, orthoclase, muscovite, garnet, staurolite, cyanite and chiastolite, and in the more basic sediments, hornblendic minerals. It is possible that these latter and similar silicates may sometimes be generated by reactions between silica on the one hand, and carbonates and oxyds, on the other, as already pointed out in some cases of local alteration. Such a case may apply to more or less hornblendic gneisses, for example, but no sediments, not of direct chemical origin, are pure enough to have given rise to the great beds of serpentine, pyroxene, steatite, labradorite, etc., which abound in the ancient crystalline schists. Thus, while the materials for producing, by diagenesis, the aluminous silicates just mentioned, are to be met with in the mud and clay-rocks of all ages, the chemically formed silicates, capable of crystallizing into pyroxene, talc, serpentine, etc., have only been formed under special conditions.

The same reasoning which led me to maintain the theory of an original formation of the mineral silicates of the crystalline schists, induced me to question the received notion of the epigenic origin of gypsums and magnesian limestones or dolomites. The interstratification of dolomites and pure limestones, and the enclosure of pebbles of the latter in a paste of crystalline dolomite, are of themselves sufficient to show that in these cases, at least, dolomites have not been formed by the alteration of pure limestones.

* Amer. Jour. Sci., II, xxxvi, 396.

The first results of a very long series of experiments and inquiries into the history of gypsum, were published by me in 1859, and farther researches, reiterating and confirming my previous conclusions, appeared in 1866.* In these two papers, it will, I think, be found that the following facts in the history of dolomite are established, viz.: first, its origin in nature by direct sedimentation, and not by the alteration of non-magnesian limestones; second, its artificial production by the direct union of carbonate of lime and hydrous carbonate of magnesia, at a gentle heat, in the presence of water. As to the sources of the hydrous magnesian carbonate, I have endeavored to show that it is formed from the magnesian chlorid or sulphate of the sea or other saline waters in two ways:—first, by the action of the bicarbonate of soda found in many natural waters; this, after converting all soluble lime-salts into insoluble carbonate, forms a comparatively soluble bicarbonate of magnesia, from which a hydrous carbonate slowly separates: second, by the action of bicarbonate of lime in solution, which, with sulphate of magnesia gives rise to gypsum; this first crystallizes out, leaving behind a much more soluble bicarbonate of magnesia, which deposits the hydrous carbonate in its turn. In this way, for the first time, in 1859, the origin of gypsums and their intimate relation with magnesian limestones were explained.

It was, moreover, shown that to the perfect operation of this reaction, an excess of carbonic acid in the solution, during the evaporation, was necessary to prevent the decomposing action of the hydrous mono-carbonate of magnesia upon the already formed gypsum. Having found that a prolonged exposure to the air, by permitting the loss of carbonic acid, partially interfered with the process, I was led to repeat the experiment in a confined atmosphere, charged with carbonic acid, but rendered drying by the presence of a layer of dessicated chlorid of calcium. As had been foreseen, the process under these conditions proceeded uninterruptedly, pure gypsum first crystallizing out from the liquid, and subsequently, the hydrous magnesian carbonate.† This experiment is instructive as showing the results which must have attended this process in past ages, when the quantity of carbonic acid in the atmosphere greatly exceeded its present amount.

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* Amer. Jour. Sci., II. xxxviii, 170, 365; xlii, 49.

† Proceedings Royal Institution, May 30, 1867, and Canadian Naturalist, new series, III, 231.

As regards the hypotheses put forward to explain the supposed dolomitization of previously-formed limestones by an epigenic process, I may remark that I repeated very many times, under varying conditions, the often cited experiment of Von Morlot, who claimed to have generated dolomite by the action of sulphate of magnesia on carbonate of lime, in the presence of water at a somewhat elevated temperature under pressure. I showed that what he regarded as dolomite was not such, but an admixture of carbonate of lime with anhydrous and sparingly soluble carbonate of magnesia; the conditions in which the carbonate of magnesia is liberated in this reaction, not being favorable to its union with the carbonate of lime to form the double salt which constitutes dolomite. The experiment of Marignac, who thought to form dolomite by substituting a solution of chlorid of magnesium for the sulphate, I found to yield similar results, the greater part of the magnesian carbonate produced passing at once into the insoluble condition, without combining with the excess of carbonate of lime present. The process for the production of the double carbonate described by Ch. Deville, namely, the action of vapors of anhydrous magnesian chlorid on heated carbonate of lime, in accordance with Von Buch's strange theory of dolomitization, I have not thought necessary to submit to the test of experiment, since the conditions required are scarcely conceivable in nature. Multiplied geognostical observations show that the notion of the epigenic production of dolomite from limestone is untenable, although its resolution and deposition in veins, cavities, or pores in other rocks is a phenomenon of frequent occurrence.

The dolomites or magnesian limestones may be conveniently considered in two classes; first, those which are found with gypsums at various geological horizons; and second, the more abundant and widely distributed rocks of the same kind, which are not associated with deposits of gypsum. The production of the first class is dependent upon the decomposition of sulphate of magnesia by solutions of bicarbonate of lime, while those of the second class owe their origin to the decomposition of magnesian chlorid or sulphate by solutions of alkaline bicarbonates. In both cases, however, the bicarbonate of magnesia, which the carbonated waters generally contain, contributes a more or less important part to the generation of the magnesian sediments. The carbonated alkaline waters of deep-seated springs often contain, as is

well known, besides the bicarbonates of soda, lime, and magnesia, compounds of iron, manganese, and many of the rarer metals in solution, and thus the metalliferous character of many of the dolomites of the second class is explained. The simultaneous occurrence of alkaline silicates in such mineral waters, would give rise, as already pointed out, to the production of insoluble silicates of magnesia, and thus the frequent association of such silicates with dolomites and magnesian carbonates in the crystalline schists is explained, as marking portions of one continuous process. The formation of these mineral waters depends upon the decomposition of feldspathic rocks by subterranean or subaërial processes, which were doubtless more active in former ages than in our own. The subsequent action upon magnesian waters of these bicarbonated solutions, whether alkaline or not, is dependent upon climatic conditions, since, in a region where the rainfall is abundant, such waters would find their way down the river-courses to the open sea, where the excess of dissolved sulphate of lime would prevent the deposition of magnesian carbonate. It is in dry and desert regions, with limited lake-basins, that we must seek for the production of magnesian carbonates, and I have argued from these considerations that much of northeastern America, including the present basins of the Upper Mississippi and St. Lawrence, must, during long intervals in the paleozoic period, have had a climate of excessive dryness, and a surface marked by shallow enclosed basins, as is shown by the widely spread magnesian limestones, and the existence of gypsum and rock-salt at more than one geological horizon within that area.* The occurrence of serpentine and diallage at Syracuse, New York, offers a curious example of the local development of crystalline magnesian silicates in Upper Silurian dolomitic strata under conditions which are imperfectly known, and, in the present state of the locality, cannot be studied.†

Since the uncombined and hydrated magnesian mono-carbonate is at once decomposed by sulphate or chlorid of calcium, it follows that the whole of these lime-salts in a sea-basin must be converted into carbonates before the production of carbonated magnesian sediments can begin. The carbonate of lime, formed

* Geology of Southwestern Ontario, Amer. Jour. Sci., II. xlvi. 355.

† Geology of the 3d district of New York, 108-110, and Hunt on Ophiolites, Amer. Jour. Sci., II, xxvi, 236.

by the action of carbonates of magnesia and soda, remains at first dissolved as bicarbonate, and is only separated in a solid form, when in excess, or when required for the needs of living plants or animals; which are dependent for their supply of calcareous matter, on the bicarbonate of lime produced, in part by the process just described, and in part by the action of carbonic acid on insoluble lime-compounds of the earth's solid crust. So many limestones are made up of calcareous organic remains, that a notion exists among many writers on geology that all limestones are, in some way, of organic origin. At the bottom of this lies the idea of an analogy between the chemical relations of vegetable and animal life. As plants give rise to beds of coal, so animals are supposed to produce limestones. In fact, however, the synthetic process by which the growing plant, from the elements of water, carbonic acid and ammonia, generates hydrocarbonaceous and azotized matters, has no analogy with the assimilative process by which the growing animal appropriates alike these organic matters and the carbonate and phosphate of lime. Without the plant, the synthesis of the hydrocarbons would not take place, while independently of the existence of coral or mollusk, the carbonate of lime would still be generated by chemical reactions, and would accumulate in the waters until, these being saturated, its excess would be deposited as gypsum or rock-salt are deposited. Hence in such waters, where, from any causes, life is excluded, accumulations of pure carbonate of lime may be formed. In 1861 I called attention to the white marbles of Vermont, which occur intercalated among impure and fossiliferous beds, as apparently examples of such a process.*

It is by a fallacy similar to that which prevails as to the organic origin of limestones, that Daubeny and Murchison were led to appeal to the absence of phosphates from certain old strata as evidence of the absence of organic life at the time of their accumulation.† Phosphates, like silica and iron-oxyd, were doubtless constituents of the primitive earth's crust, and the production of apatite crystals in granitic veins, or in crystalline schists, is a process as independent of life as the formation of crystals of quartz or of hematite. Growing plants, it is true, take up from the soil or the waters dissolved phosphates, which pass into the skeletons

* Amer. Jour. Sci., II, xxxi, 402.
† Siluria, 4th ed., pp. 28 and 537.

of animals, a process which has been active from very remote periods. I showed in 1854 that the shells of Lingula and Orbicula, both those from the base of the paleozoic rocks and those of the present time, have (like Conularia and Serpulites) a chemical composition similar to the skeletons of vertebrate animals.* The relations of both carbonate and phosphate of lime to organized beings are similar to those of silica, which, like them, is held in watery solution, and by processes independent of life is deposited both in amorphous and crystalline forms, but in certain cases is appropriated by diatoms and sponges, and made to assume organized shapes. In a word, the assimilation of silica, like that of phosphate and carbonate of lime, is a purely secondary and accidental process, and where life is absent, all of these substances are deposited in mineral and inorganic forms.

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I have thus endeavored to sketch, in a concise and rapid manner, the history of the earlier rock-formations of eastern North America, and of our progress in the knowledge of them; while I have, at the same time, dwelt upon some of the geognostical and chemical questions which their study suggests. With the record of the last thirty years before them, American geologists have cause for congratulation that their investigations have been so fruitful in great results. They see, however, at the same time, how much yet remains to be done in the study of the Appalachians and of our northeastern coast, before the history of these ancient rock-formations can be satisfactorily written. Meanwhile our adventurous students are directing their labors to the vast regions of western America, where the results which have already been obtained are of profound interest. The progress of these investigations will doubtless lead us to modify many of the views now accepted in science, and cannot fail greatly to enlarge the bound of geological knowledge.

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* Amer. Jour. Sci., II, xvii, 236.

## ABSTRACT OF PAPERS READ BEFORE SECTION B.

### The Monocotyledon the Universal Type of Seeds. — By Thomas Meehan.

It must be evident to those who heard my paper on "Adnation in Coniferæ" at the Chicago meeting of the Association that the observation there detailed, could scarcely be accounted for, if the belief be true which is generally held by botanists, that *the leaf originates at the node from which it seems to spring*. It is not, however, an object with me to attack existing theories, or establish new ones; but simply to present facts as I see them. The origin of the leaf will no doubt prove a question which will in time take care of itself. But this generalization cannot be avoided by the readers of that paper, that the whole plant is originally a unity; and that the subsequent formation of elementary organs, and their complete development, or absorption into one another, is the result of varying phases of nutrition. The leaves in Coniferæ were found to be free or united with the stem in proportion to the vigor of the central axis. Following up the subject I now offer some facts which will show that all seeds are primarily Monocotyledonous; and that division is a subsequent act, depending on circumstances which do not exist at the first commencement of the seed growth.

It is well known that in some species of Coniferous plants the number of cotyledons varies. I have noticed in addition to this that whether the cotyledons are few or many, *there is no increase in the whole cotyledonous mass*. In the Norway spruce, *Abies excelsa*, there are sometimes as many as ten cotyledons, in others only two. In the latter case they are broad and ovate, while in the former they are narrow and hair-like; in short, when in the two cotyledoned state it is not possible to note any difference between a seedling Norway spruce and a Chinese arbor vitæ, *Biota orientalis*, except by the lighter shade of green. The two leaved condition is not common, but specimens of threes and others I exhibited to Drs. Torrey and Gray at the Troy meeting. Any one who will examine sprouting seeds of the Norway spruce will agree to the proposition

that the *cotyledons are not original and separate creations, but a divided unity.* My next observations were on some acorns of *Quercus agrifolia* the division into cotyledons was numerous and irregular. Cut across vertically some representing the letter C, others the letter N, and again, with four cotyledons the letter M. Here again it was clear that whatever the form and number of the cotyledons *there was no increase of the original cotyledon mass.* Examining sprouting peach kernels, the variations in form and number were of the most remarkable character. I need not repeat them in detail here, as they are reported in the April and May "Proceedings of the Academy of Natural Sciences of Philadelphia." In addition to the fact of no increase in the whole cotyledon mass, it was here clear that *when the cotyledons were duplicated, the duplications at least were subsequent to the original ones.* Still so far nothing had been seen to indicate when the first pair of cotyledons were formed. *Quercus macrocarpa* and *Quercus palustris* were silent to my questions. In a large number I found no variations whatever. Each mass was divided smoothly and exactly into two cotyledons. *Quercus robur*, the English oak, however gave some curious evidence. Two germs under one seed coat were numerous and often three, and the cotyledons took on a variety of forms. But there was never any more increase in the cotyledonous mass, than if but two lobes had been formed and there was no more rule in the division than there would be in the sudden breakage of a piece of glass. A detailed account of these will also be found in the "Proceedings of the Academy of Natural Sciences of Philadelphia" for May. *Quercus rubra*, the American red oak, furnished the one link wanting to connect the first division into lobes with the other phenomena. *All* the acorns examined had three or four sutures on the cotyledon mass, and extending all along the longitudinal surface externally, without any reference to cotyledonal divisions. These sutures extended sometimes but a line in depth, at others almost to the centre of the mass, always accompanied by the inner membrane, as is the case in ruminated seeds. The whole mass was divided only in two parts in any that I examined of this species, but the division was always in *the direction of the sutures.* Hence each cotyledon was very irregular. Sometimes one-third the mass only went to one while the other had two-thirds of the whole mass. *It was easier to burst in the weaker line of resistance.* But

the interest for us is to note that originally the cotyledonous mass was a unit — then the sutures or fissures were formed; and ultimately the two divisions of the lobes followed in their direction. *The division was the last condition, not the first.* I know how much we should guard against generalizing on a limited supply of facts, but it requires an effort to believe that oaks, pines, and peaches, as we have seen primordially monocotyledons, are in this respect different from other so called dicotyledonous plants; and if we grant that all seeds are primarily monocotyledonous, may we not ask *why in any case are they divided?* We have seen that there is no increase of mass in the division, the same amount is furnished in one as in many. Would it in any way injure the Indian corn to have its mass divided into two lobes? or would not the plantlet be as well provided for if the acorn were in one solid mass? Division would seem to be a necessity, occurring subsequent to organization, and existing from the position of the plumule alone. In monocotyledons, as we know, the plumule is directed parallel to, or away from the cotyledonous mass, when of course, on this theory it remains an undivided mass. But in the dicotyledonous selection, the plumule is directed towards the apex of the mass and as we know in the case of roots against stone walls, or mushrooms under paving stones, the disposition in the growing force of plants is to go right forward, turning neither to the right nor the left; so in this mass of matter the development of the germ would make easy work of the division; and no doubt often at so early a stage as to give the impression we have been under hitherto, that the division is a primary and essential process.

Prof. GRAY remarked that he was not disposed now, in the absence of Mr. Meehan, and upon the consideration of a paper upon a wholly independent topic, to discuss the author's views upon "Adnation in Coniferæ;" but Mr. Meehan was well aware that they were not quite consistent with the ordinary vegetable morphology. It was more agreeable to be able to say that Mr. Meehan's conclusions, that the apparently polycotyledonous embryo of many Coniferæ is only dicotyledonous, must undoubtedly be regarded as correct. This view was satisfactorily proved by Duchartre, ten or fifteen years ago, and is adopted by Parlatore in the elaboration of Coniferæ for De Candolle's Prodromus, published three or four years ago. But Prof. Gray thought that the appearances in the embryo of oaks, which Mr. Meehan had brought up as evidence that the dicotyledonous embryo was a mere deviation of the monocotyledonous,

and especially that the two cotyledons originated as it were from the splitting up of one, would not be regarded by botanists as in any degree convincing. He presumed that Mr. Meehan perceives that it directly follows from this doctrine that in all opposite leaves the two are organically one, and he would leave to him the undertaking of reconstructing morphology and phyllotaxis upon such a basis.

Dr. T. C. HILGARD remarked, that the whole question came back to the laws of phyllotaxy. The very fact of these "genetic" numbers, as he had called them, required the second element to be derived from the first one; as all radial organs must be derived from their predecessors. The fact itself was apparent in the far too much neglected phenomena of cryptogamous *developments* (or "embryology" of authors). The moss-spore proper (apart from the *Chlorospermeæ* as true moss-*spawns*), develops into a true land (or aquatic) Conferva. The latter bears a bud at the ends of its thread-like "prothallium." Each of its cells is generated out of a preceding one. A terminal cell enlarges into a conical leaf. *Out of that leaf* springs the second, at its base. It is in fact only on the supposition of radial organs generating their successors at the side of the *rift* — at the centre — alternating from either border (as in the case of the pod-leaves, producing fertile ovules), that the whole of phyllotaxic phenomena, and of organic numbers in general, becomes explicable. The production of new elements, however, takes place in a very embryonic condition. Cotyledons already formed do not *divide*. Lobes of fissures, folds, etc., of cotyledons are no divisions, but are due to unequal enlargement. New elements are not formed by division, but by sprouting.

MECHANISM OF FLEXION AND EXTENSION IN BIRDS' WINGS. — BY DR. ELLIOTT COUES.

DR. COUES' proposition is, that flexion of the forearm upon the humerus produces flexion (adduction) of the hand upon the forearm, by osseous mechanism alone, and conversely: extension of the forearm causes extension (abduction) of the hand. The point of the article consists in a demonstration of the fact that, in spreading and folding the wing, the radius slides lengthwise along the ulna to a certain extent. Recapitulating certain points in the anatomy of the elbow and wrist, the author shows that this sliding is produced by the relative size, shape and position of the humeral surfaces with which the radius and ulna respectively articulate; these being such, that in flexion of the forearm the radial surface is nearest the wrist-joint, and in extension the ulnar one; and consequently the two bones of the forearm occupy different relative positions in flexion and ex-

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## Mechanism of Flexion and Extension in Birds' Wings. — By Dr. Elliott Coues.

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tension. In flexion, the radius is pushed forward, and projects somewhat beyond the end of the ulna, impinging upon the radio-carpal bone (scapholunar), and pushing the pinion around the centre of motion of the wrist-joint so that it is more or less flexed. In extension, the reverse motion takes place, from the pulling back of the radius. The proposition is carefully demonstrated, illustrated with three figures, and likewise shown to be susceptible of ocular proof by direct experiment. Several interesting corollaries are also drawn. Some such mechanism is shown to be an anatomical necessity, from the structure of the wrist-joint, to provide for the extremes of adduction and abduction that take place in the wrist, without straining the joint. Another obvious purpose subserved is equalization of muscular power, by relegating a part of the work, that the hand muscles would otherwise have to perform, to the larger flexors and extensor of the upper arm; and an actual saving of a certain amount of muscular effort, this being replaced by automatic movements of the bones themselves. Having seen no account of this mechanism, the author is inclined to think it may be unnoticed.* It is at any rate a new explanation of the design of the peculiar shape and position of the radial articulating surface of a bird's humerus, far more important than that hitherto assigned, viz.: its causing simply the well-known *obliquity* of flexion of the forearm.

On the Geological History of the Gulf of Mexico.—By Prof. Eug. W. Hilgard.

This paper, accompanied by a geological map, treats of the formations that have gradually filled up the ancient Mississippi embayment, existing after the upheaval of the Palæozoic rocks; whose vertex, a few miles above the junction of the Ohio and Mississippi, is marked by the small Tertiary area in Illinois. The author hopes that a close comparison of these deposits with those of the Far West, with which they were and partly still are connected, may lead to the more accurate parallelization of the latter with the marine deposits of more distant regions. Most of the subject

* It is indeed not mentioned in the works of Cuvier, Meckel, Tiedemann, Wagner, and other distinguished authors; but Dr. Bergmann, of Gottingen (*Archiv. fur Anat.*, 1839, 296), speaks of essentially the same thing, although the results of the mechanism are not so fully shown.

matter here referred to is embraced in the author's publications for ten years past.*

The most ancient shoreline of this embayment is formed chiefly by the Carboniferous rocks. The oldest formation cropping out within these limits is the Cretaceous, which east of the Mississippi traverses the states of Alabama, Mississippi and Tennessee, reaching a short distance into Kentucky, along the Carboniferous ridge which borders the Tennessee river. The dip is 20-25° at right angles to the trend of the formation, which in its southerly portions is very distinctly subdivided into three chief groups, whose equivalents seem to be readily traceable in the Northwest. But towards the northern, narrow end of the outcrop, the distinctions become less defined, and the character more or less lignitic.

West of the Mississippi, in Arkansas, the outcrop does not extend so far north by some one hundred and fifty miles. It there corresponds to the middle group, the lowest not having thus far been recognized; while the upper one appears to be represented in the series of Cretaceous outliers existing in Louisiana, forming, apparently, a Cretaceous "backbone" to that state, whose southernmost point is, probably, the rock-salt mass of Petite Anse. The sulphur and gypsum of Calcasieu, likewise, seem to belong to this epoch, but their precise mode of formation can at present only be guessed at.

During the Tertiary period, the shoreline receded from its extreme head in southern Illinois, to near the latitude of Baton Rouge, running nearly parallel to the present one. This seems to show comparative shallowness; and this point is confirmed by the predominantly lignitic and lignito-gypseous character of the deposits, especially in the upper part of the embayment, where small outliers only of a marine character exist. The lignitic feature repeats itself throughout the predominantly marine deposits of the later times; less so in Alabama than in Mississippi, while in Louisiana it largely predominates, owing probably to the presence of the Cretaceous "backbone." In general each marine group has its lignitic equivalents; and since lignitic outliers connect across Texas, with the great basins of the interior, a close study of their flora (and possibly fauna) may, it is hoped, enable

*Rep. on the Geology and Agriculture of Mississippi, 1860. Am. J. Sci. May 1866; Ibid. July 1866; Ibid. Nov. 1866; Ibid. Jan. 1867; Ibid. Jan. 1869; Ibid. Nov. 1869. Rep. U. S. Engin. Dept. 1870; Am. J. Sci. March, April and May, 1871.

us to determine the equivalents in time of the marine Tertiary groups.

The Vicksburg series of rocks, ends the marine Tertiary of the Southwest; the transitions between its fauna and the older Eocene are so cogent as to render any great separation in time or space inadmissible. The Vicksburg deposits are rather of a deep-sea character, less lignitiferous than the stage next below. But the Miocene and Pleiocene deposits, observed on the Atlantic coast, are unrepresented on the waters of the Gulf, save by beds equally devoid of a marine or fresh water fauna, and with but very few and poorly preserved remains of plants. A single fragment of a turtle has been found in a clay stratum filled with calcareous concretions, possibly the remains of a fauna destroyed by maceration. These "Grand Gulf" beds lack all analogy outside of the Gulf basin, unless it be in the interior, perhaps, in the Bad Lands of Nebraska, whose analogues have now been found so much farther south than heretofore supposed, that a connection may have been possible; the lithological resemblance is very great — at all events, since the Grand Gulf rocks alone represent the period between the Eocene and Drift, they include the equivalents in time of the White river beds as well as others.

It seems impossible to account for the character, thickness and position of these beds, without assuming that after the close of the Eocene period, the Gulf was either cut off from the Atlantic, or communication was so slight as to cause the continental waters to freshen the brine so much as to destroy the marine fauna, without rendering it fit for fresh water life. An upheaval of the northern border of the Caribbean would even now readily produce such an isolation, were it not for the deep channels excavated by the Gulf stream, in the straits of Yucatan and Florida. Since on the farther Antilles Miocene and Pliocene beds have been found, it is evident that this state of things was confined to the Gulf basin. The geology of Cuba and Yucatan is too little known to determine how far they were concerned in the same.

The Grand Gulf as well as the older rocks are almost everywhere overlaid by the "Orange Sand" or stratified Drift; while on the Palæozoic territory it is more or less localized in conformity with the larger valleys. On the area under consideration, it forms a huge delta-shaped mass, consisting mainly of ferruginous and variegated sand and subordinate clay beds, and traversed by

several pebble streams, the largest of which occupies the axis of the embayment. Its beds disappear beneath those of the Port Hudson era almost concurrently with the Grand Gulf rocks.

The phenomena offered by these deposits, as heretofore shown, require the assumption that prior to its deposition the Gulf coast suffered an elevation of at least four hundred and fifty feet above its present level, accompanied by a much greater one at the head of the waters. Then there occurred a slow depression to about twice that amount, and finally, during the Terrace epoch, a reëlevation to at least the extent of four hundred and fifty feet. The northern derivation of the pebbles, their size, and the extensive plowing-up of older beds, prove a southward flow of waters, of considerable violence.

These events were of no local character; they are intimately connected with, and the complement of, the Drift phenomena of the Northwest. It is time that the facts of the case were generally understood and taken into account by American geologists, and that the Ohio should cease to be proclaimed the southern limit of the Drift. Its southern representative has mostly, heretofore, been erroneously associated with contiguous formations of every age.

An understanding should be come to as to what is meant by the word "Drift." In New England it means chiefly moraine material; in the West, what is presumed to be iceberg drift; in the South, materials clearly stratified and transported almost exclusively by water. All are properly included in the *Drift Epoch*, defined as embracing the time between the termination of the Tertiary, and the beginning of the Champlain era of quiet deposition and slow depression.

The next succeeding formation is the Port Hudson series of swamp, lagoon, fluviatile, estuarian and littoral deposits, formed during the slow depression of the continent. It underlies not only a wide littoral belt, now partially covered by the waters of the Gulf, but also the entire alluvial area of the lower Mississippi, Red, and other larger rivers, then constituting extensive fresh water estuaries; their general valleys having, evidently, already been impressed upon the surface during the later Drift period, though not always coincident with their present ones. Late observations made in the Yazoo and Tensas bottoms confirm the statement, made by Gen. Humphreys in 1860, that the Mississippi

and its bayous have mostly cut their channels into a clay formation foreign to the alluvium, from which some of the best soils of these bottoms are also directly derived; the alluvium being, on the whole, of little thickness.

These clays form the lower division of the Port Hudson beds. The upper consists chiefly of yellow and whitish silts which at some points form a terrace along the edge of the bottom; while on the hilltops of the adjoining uplands lies the calcareous, silty loam (Loess), of the Bluff formation, differing from its equivalents farther north by the total absence of stratification, and the exclusive prevalence of terrestrial fossils. How this state of things was brought about, it is not easy to imagine, unless perhaps the tidal flow was instrumental therein.

Above the Loess we find usually a stratum of loam or brick clay, which near the larger rivers is sometimes 15–20 feet in thickness. It is devoid of stratified structure as well as of fossils, and forms the sub-soil of most of the uplands of the Gulf States.

The Terrace epoch has not left any marks in the way of beach lines or terraces distinctly referable to that era. As regards the modern epoch, the Mississippi Delta presents the anomaly of progressing, not by simple alluvion, but through the singular agency of the Mudlumps, discussed in a paper lately published.*

Col. CHARLES WHITTLESEY said he was gratified to find so many facts conspiring to sustain a theory of his own and a favorite theory of fifteen years standing, that the Quaternary of the Lower Mississippi is cotemporary with the later epochs of the Northern Drift.

He thought it was now demonstrated that the bluff or Loess beds of the upper and lower Mississippi are identical. At the north there are instances of coarse transported materials overlying and underlying the Loess. The blue, variegated, and red clays of the upper beds are closely allied in age with the Loess and are probably cotemporary with it and the Champlain clays.

This Loess or bluff stratum extends from above the Falls of the Mississippi to below Natchez, and forms a connecting link between the gulf deposits and those of the north. He suggested that there was a reasonable explanation of their common origin when we consider that the Glacial period was one of great length, and also considering the state of things as it was gradually drawing to a close. Such a vast accumulation of ice and nevè, exceeding two thousand feet in thickness, required a long period for its dissolution, and in dissolving produced a vast fresh water sea, covering a country nearly flat, but having a drainage to the south.

* Am. Jour. Sci., March, April and May, 1871.

The currents must have been broad, powerful and deep, and operating always in one direction, were capable of transporting materials of considerable coarseness a thousand miles. Hence mud, loam and clay would be carried indefinitely. Agates and cornelians, whose home is in trap rocks above the Falls of St. Anthony, are found scattered along the valley to the mouth of the Ohio. If they travel at the rate of only a rod in a year, three hundred and twenty years would find them advanced a mile gulfward, and ten thousand years more than thirty miles. A current of four miles an hour, extending from the western base of the Cumberland Mountains in Tennessee to the foot of the Ozark Mountains in Missouri would fill up a space equal to a large state in a century.

It appeared to the speaker that here is a simple and sufficient explanation for the translation, in the later parts of the ice period, of so much northern gravel sand, loam, and even of small boulders to the vicinity of the gulf and into it.

Below the states north of the Ohio, pieces of the native copper of Lake Superior are not found in the Quaternary gravel. The water forces were not equal to the transportation of so heavy a material, nor of magnetic iron boulders and gravel. Both the copper and the heavy iron ores of Lake Superior are common in the Drift of the Lake country, but they required the propelling force of moving ice to send them along. Beyond the ice or glacier field, deep and persistent currents of water were able to take up and move forward the lighter materials to places many hundred miles distant, provided the element of time is sufficiently great.

In this way we may synchronize the whole field of the Quaternary of the United States east of the Rocky Mountains and perhaps that of the Pacific slope.

Dr. C. A. WHITE was much interested in the able paper of Professor Hilgard, especially as hitherto so very little has been brought out concerning the phenomena of the Post-tertiary period in that latitude. While conceding the facts observed, and the conclusions arrived at by him there, I must, nevertheless, maintain that we of the Upper Mississippi valley have not been mistaken in ours. In Iowa we have a very different set of Post-tertiary phenomena, and yet I believe true explanations of both may, and ultimately will be, completely harmonized by careful study of the broad region intervening between those that he and I have respectively studied.

The Post-tertiary deposits of Iowa consist of the true, unaltered, unstratified Drift, so well known in that region and elsewhere, through the more or less distinctly stratified gravelly or sandy drift observable in the valley sides above the reach of floods, to the alluvium of their flood-plains. Besides this, we have, in Western Iowa, that very interesting deposit resting upon the drift which Professor Swallow has called the Bluff deposit. This deposit, doubtless, had essentially the same origin as that to which Professor Hilgard has given the same name in Louisiana, namely, in the muddy waters of the Missouri river, although the deposit, doubtless, never had direct continuity, but was interrupted by broad

barrier elevations of the surface, through which the river cut its valley during the Terrace epoch, as I have defined it for our region. I have been able to recognize there only two epochs of the Post-tertiary period, namely, the Drift and Terrace epochs; but, at the same time, I fully concede all that is claimed for the existence of phenomena upon the sea-coasts upon which the Champlain epoch is based. The Drift epoch, with us, is understood to have ended with the disappearance of the ice, and the Terrace epoch to have continued from that time to the present. The terraces I understand to be parts of flood-plains abandoned from time to time as the valleys were deepened by the action of the waters of their own streams, for I can see no evidence that they were produced, even in part, by any elevations or depressions of that part of the continent. At the close of the Drift epoch, we may assume that Iowa had a nearly level surface, averaging, as it does now, about eight hundred feet above the level of the sea, the highest point being about seventeen hundred feet above, and the lowest, the southeast corner, four hundred and forty-four feet above that level. The valleys have all been eroded out of this general level by their own waters, and this is believed to be quite sufficient to account for the existence and character of the terraces. These terraces are found in the Bluff deposit as well as in the altered Drift, showing that the Bluff deposit must have originated early in the Terrace epoch. The deposit was formed in a large lake-like expansion of the Missouri river, caused by a broad depression that was left in the surface of the Drift at the close of the Drift epoch, and became filled with the silt of the muddy stream that flowed into and from it, which, finally deepening its valley below, had only to sweep out a part of the silt, which became the Bluff deposit, leaving the terraces, as it did, in the Drift.

Professor A. WINCHELL felt prepared to corroborate fully Dr. Hilgard's views in reference to the absolute continuity of the upper portion of the Drift deposits in the Northern and Southern States. He had studied these deposits from the Gulf of Mexico to Lake Superior, and in the Southern States, especially along the Black Warrior and Alabama rivers, and had expressed the conviction to Prof. Tuomey as long ago as 1852, and had published it in the "Cleaveland Proceedings of the Association" in 1853, that he found no grounds for assigning the semistratified deposits of the Southern States to a different age from the so-called "altered Drift," of the North. They all seem to be composed of similar materials (modified certainly by local circumstances), and to have been transported from the higher lands of the continent at the same time, and by agencies of a similar character.

Dr. G. LITTLE had studied this subject for a quarter of a century. When a small boy it was his custom with his playmates to "fight rocks;" one boy would take one of these pebbles from the immense gravel beds on which the city of Tuscaloosa, Alabama, is located and attempt to break another chosen by his companion. Although ignorant of mineralogy, he soon discovered that those pebbles which were clear and glass-like (Quartz) proved the hardest to break — they were sometimes half as

large as a boy's head, more frequently of the size of the fist — very smooth on the surface, and often egg-shaped. It was a matter of curiosity to him to inquire whence these rocks came and how they became rounded and polished.

Some years later he was so fortunate as to become a pupil of Prof. M. Tuomey in the University of Alabama. That excellent geologist, at that time, twenty years ago, attributed the gravel beds, on which Tuscaloosa and several of the capitals of the Southern States (Milledgeville, Ga., Columbia, S. C., Richmond, Va.), are situated, to the same agency whose action was described in the north as producing the Drift phenomena.

At a still later period, as State Geologist of Mississippi, Dr. T. traced these beds from Tuscaloosa to Columbus, Miss., to Eastport, Tenn., and along the edge of the Carboniferous to the Ohio. The same beds he saw along the northern lakes. From these high northern latitudes came then the materials of what is called Drift in the Southern States by Dr. Hilgard, in his paper. Quartz, from its hardness, furnishes the largest pebbles and the sand grains. The coloring matter of the Red Clay which forms so much of the surface of the Gulf States comes from the iron beds of Lake Superior.

Professor PERRY, having recently made a somewhat detailed examination of the principal geological formations in Mississippi, was happy to be able to say that he had not become acquainted with a fact which militates against the main views advanced by Professor Hilgard.

While all geologists are familiar with the three series of Cretaceous formations in Alabama and Mississippi, it may be proper for me to mention that Cretaceous deposits of peculiar interest have been recently discovered by Professor Kerr, at Snow Hill in North Carolina. Under his guidance, I had the pleasure of visiting the locality, last spring, shortly after their discovery. They appear to be of about the same age as the Ripley group of Mississippi, and are equally rich in organic remains; while they contain according to Professor Conrad a large number of genera and species new to science. The discovery is destined, no doubt, to add a new chapter to the history of the American Cretaceous.

After a rather careful investigation of the Tertiary beds of Mississippi, I have found no occasion to take exception to the main conclusions reached by Dr. Hilgard and published in his Geological Report of the State. Of the uplift to which he refers in his report and in the paper read, running about west-north-west and east-south-east, which was first mentioned by Professor Tuomey, I found abundant evidence in both Alabama and Mississippi.

In regard to the existence of Mississippi Drift, the subject of more especial interest at this time, I may say that I find no room for doubt. The prominent features of this formation, as it occurs in Mississippi and Alabama, I had opportunity to study between the years 1847 and 1850. I then became acquainted with the phenomena, while their explanation has been only gradually reached by the continued studies of subsequent years.

During the past season, I desired, as occasion was afforded, to verify or disprove, by an actual list of facts, the previous views in regard to the question of southern Drift. Taking the circuit of the Atlantic and Gulf States, and thence proceeding up the valley of the Mississippi, I discovered at almost every step what to me is unmistakable evidence of glacial agency, all the way around from Virginia to Illinois. I have studied the Drift of New England for years, I think I know it in its main features —typical Drift and modified Drift in most of its varying forms. Now, in all the states referred to, I found that which I could not distinguish, after making the necessary allowance for local differences, from New England Drift.

As to the direction in which the agency worked, I find variations which were, no doubt, eagerly determined by the face of the country; variations which indicate that the deposits assumed the form which they now have, in what was the closing part of the Glacial period, in the Southern States. The beds seem to go out in rays from the Appalachian mountains, from the Blue Ridge towards the Atlantic, in the Gulf States for the most part southward, and in the Basin of the Mississippi towards the southwest.

Reference having been made to a supposed elevation and depression of the country, I would suggest that the facts relied on as evidences are perhaps susceptible of another and more simple explanation. Remembering that, in the formation of the immense ice-mass that spread over much of the continent, there must have been a considerable depression of the ocean; also that the thawing of the extended mass of ice at the close of the Glacial period must have produced immense floods of water, we have what was no doubt equivalent to a moderate elevation and depression, and a cause sufficient to account for all the manifestations of glacial agency with which we meet.

Prof. E. C. ANDREWS said that in the prosecution of the geological survey of the State of Ohio by Prof. Orton, he found in the Drift deposit, buried beneath eighty feet of drift material, a peat-bed and a buried forest containing wood, plants and mosses in their original position, and so perfectly preserved that a number of living species have been identified. That is in the very midst of our drift material in Montgomery county, in Southern Ohio. The formation there is coarse gravel and drift material, and I think not stratified.

Prof. RICHARD OWEN mentioned that it has not been adverted to, that on the north shore of Lake Superior the rocks which have furnished the Drift that we find in the whole Mississippi Valley are in sight. Then, as we go south, these detached boulders are found at first in large, then in smaller and constantly smaller fragments, ranging in size from those of many hundred tons weight down to a ton or two in this region, and finally, south of the Ohio river, weighing only perhaps from one hundred to one hundred and fifty pounds and those giving place in turn to deposits in the form of sand, ending finally in beds of sand on the shores of the Gulf of Mexico. Now, without stopping to advert to the great theory as

to the elevations which brought up the Apallachians and the Rocky Mountain ranges and sent this Drift centrifugally through, I will merely say that there are portions of Indiana in which, when we go through that gravel, we find rocks that have been polished off and then grooved in a north and south direction, which proves that from the rocks away north of Lake Superior, the northern and southern Drift are continuous, becoming smaller as you go south, borne there by the oceanic currents, and afterward, as the land rose, dropped in the form of fresh water deposits, accounting for the large boulders in the north, the beds of gravel in the south, the beds of peat and all the varied phenomena that have been observed in connection with the subject of the Drift.

Professor HILGARD remarked, in reply, that, in the South at least, the Drift epoch was easily defined as reaching from the termination of the latest Tertiary period to the beginning of the deposition of the Port Hudson beds (equivalent to those of Dana's Champlain period); when all deposits that could properly be designated as "drifted," ceased to be formed outside of river channels. Where the Champlain depression had not caused submergence, it might be marked by subaërial deposits, such as had been observed in an apparently corresponding position, by Dr. Edmund Andrews, of Chicago. He thought the southern stratified Drift corresponded to the "modified Drift" of the West, though on a very large scale; but it would not do to call it by that name, which could apply only to a small portion in the axis of the embayment. Elsewhere it was modified Carboniferous, Cretaceous and Tertiary; the materials of these formations having been simply plowed up and redeposited farther south by the Drift waters. No name could be altogether distinctive and characteristic, yet in this case the stratification was so to a very great degree, and he thought the name of "Stratified Drift" might properly be made to embrace the southern Drift as well as the "modified" Drift of the Western States.

At the present time, the winter ice of the Mississippi frequently runs past Vicksburg. How much more must the ice-floes and bergs of the Glacial period have reached at least that latitude, down to which we find, even though rarely, boulders of northern derivation, too ponderous and too little worn to have been transported by water alone. Quartzite pebbles of a couple of pounds weight occur even at the island of Petite Anse, together with other smaller ones of northern rocks; and a profusion of those derived from the Grand Gulf rocks, whose nearest outcrop lies about sixty miles due north.

In reply to a question as to what he now thought of the age of the rock-salt deposit of Petite Anse, Prof. HILGARD stated that he thought it of the Cretaceous age. It was older than the Drift, by which it was overlaid; and its great thickness and purity, as well as the absence of analogy, militated against its connection with any of the Tertiary stages. On the other hand, the Cretaceous of northern Louisiana was preëminently salt-

bearing, and Petite Anse lay right in the line of a series of Cretaceous outliers indicating an axis of upheaval, Cretaceous limestone occurring within sixty miles of Petite Anse. Moreover, the limestone and gypsum of Calcasieu, between which lies the sulphur bed, are distinctly represented in the Cretaceous of northern Louisiana, while totally foreign to any of the Tertiary stages; and although the great gypsum bed has not been reached at Petite Anse, it lies in the proper line of dip, and seems to form a complement to be looked for, of the great rocksalt bed. These probabilities fall short of proof, it is true, but weigh heavily when we consider the simplicity of the geological structure of the Mississippi embayment; where departures from the general rule are so unlikely as to throw the burden of proof upon whosoever maintains their existence.

On the Carpal and Tarsal Bones of Birds. — By Prof. Edward S. Morse.

The author stated that he had followed with great interest the work of Huxley, Cope, and others in tracing out the ornithic characters in the Dinosauria. While following these relations he had noticed a marked difference in the characters of the carpus and tarsus of the two classes. It seemed strange that a group of bones so persistent in the reptiles as well as in the mammalia should be so obscure or wanting in birds. Owen objects to the term tarso-metatarse as he believes the existence of a tarsus has not been demonstrated. W. S. Parker, in 1861, on the osteology of Balœniceps, questions if the lower articular portion of the tibia is not the homologue of the mammalian astragalus and not an epiphysis. Gegenbaur has now shown that in one stage of the young bird there is a proximal tarsal ossicle, and a distal tarsal ossicle, the first one anchylosing with the tibia, the distal one likewise anchylosing with the metatarse. Thus, the term tarso-metatarse is quite proper. While this was a great step toward a proper understanding of these parts, Mr. Morse believed that a nearer relation would be found in the discovery of another proximal tarsal bone. In those reptiles he had examined, whatever the number of tarsal bones, there were always in the proximal series one corresponding to the tibia, and another corresponding to the fibula. He had found this feature in birds. In studying the embryos of the eave swallow, bank swallow, king bird, sand piper, black bird, cow black bird, blue bird, chirping sparrow, yellow warbler, and Wilson's thrush, he had found three distinct tarsal bones, two in the proximal series answering to the tibia and fibula, and one in the

distal series. The first two early anchylose, and present an hour-glass-shaped articular surface as Prof. Cope has described in the astragalus of Lœlaps. The final anchylosis of these conjoined ossicles with the tibia, formed the bicondylar trochlea so peculiar to the distal end of a bird's tibia. The distal tarsal ossicle became united with the proximal ends of the metatarse as has been shown. In the carpus he had found four perfectly distinct ossicles, the distal carpal bones becoming united to the base of the mid- and outer metacarpals, the other two remaining free, though the ulnar carpal in some cases anchylosed with the ulna. In the king bird and yellow warbler, he had found a fifth carpal on the radial side.

Mr. Morse also described the pelvic bones of an embryo sparrow, though he supposed these had already been worked up.

When Professor Morse mentioned his doubt about the natural position of the ischium of a certain saurian with reference to a lateral process of the same, Dr. T. C. HILGARD remarked that every pelvis consisted, besides the sacrum, of five, not three only, separate bones on either side; the *crista ilii* being, in mammals (*i. e.* young dog), a separate, crescented rim, sutured to the hip-blade; and, in a like manner, the *tuberositas ischii* was related to the *ischium*. They are the fourth and fifth elements, which by the genetic law of numbers, ought actually to have sprung from the first (ischium) and second (ilium), respectively, to which they adhere. The third bone was the *os pubis*. In birds, the tuberositas forms a gristle, which, in "spring-chickens," is seen ossified as a bone or process, etc., connecting the ischium sidewise with the rearward prolongation of the ileum, and forming a recess for the attachment of a pelvic muscle. In chickens this bone takes the shape of a boomerang, and perhaps the Polynesians found that instrument ready made in the "spring-dinornis." It forms various processes according to the first location of its nucleus.

Dr. C. A. WHITE, asked if no attempt had been made to specially homologize these carpal and tarsal bones of birds. Since those adjacent both distally and proximally had been thus homologized, it seems as if it would not be very difficult to do the same for the smaller bones of the carpus and tarsus. Perhaps they may, just before they anchylose, present pseudoarticular facettes that will give a valuable clue to their special homologies by comparison with similar parts of limbs of mammals.

## On the Characteristics of the Primary Groups of the Class of Mammals. By Dr. Theodore Gill.

At the last meeting of the Association, the author made a communication on the classification of mammals, based on facts in part already become the common property of science, and in part hitherto unpublished. An abstract giving the conclusions arrived at has been published in the American Naturalist and in the Proceedings of the Association. Continued researches into the same subject have confirmed the propriety of the ordinal groups and the limits then admitted, but have necessitated a different combination of those groups.

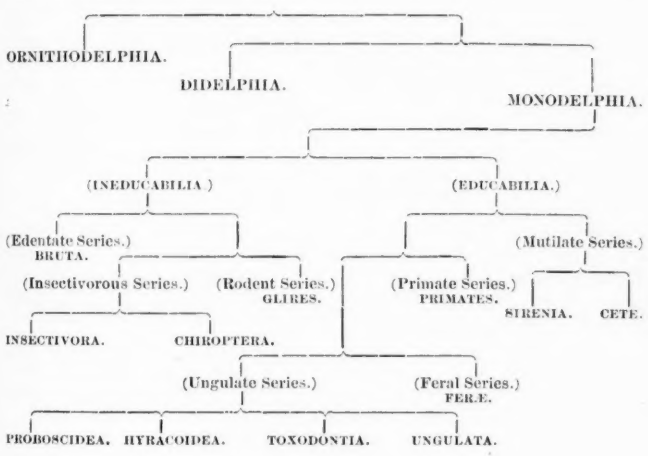
The divisions into sub-classes first solidly established by Huxley are retained.

The Placental or Monodelphian mammals are with more propriety combinable into two major groups which correspond; on the one hand, to the Educabilia of Bonaparte, the combined Archencephala and Gyrencephala of Owen, and the combined Archonts and Megasthenes of Dana; and on the other hand, to the Ineducabilia of Bonaparte, the Microencephala of Owen and the Microsthenes of Dana. The characters hitherto used to distinguish those groups are however either vague and difficult of application, not characteristic, or generally regarded as erroneous. But positive and easily recognizable characters appear to exist in the brain which confirm those groups, but which have not hitherto been regarded, at least in respect to their systematic application.

There has also always existed cause to deplore the insufficiency of the characters assigned in the diagnoses of some of the orders of mammals. After an attentive study of most of the known forms, the author believes that he has succeeded in finding characters which at the same time confirm the groups already recognized and supplement the teleological characters (sometimes of doubtful application or entirely failing) by morphological characters of more constancy. The revised diagnoses of the orders and other primary divisions are submitted in advance of a work now being printed by the Smithsonian Institution; that work will give the characters, contrasted in dichotomous tables, of all the groups of mammals as low as subfamilies and lists of the genera, recent and extinct. While the author has been dependent, for the most part,

on the collections of the Smithsonian Institution for his investigations, he has also visited the museums of the Academy of Natural Sciences of Philadelphia, the Peabody Academy of Science of Salem, the Boston Society of Natural History, and the Museum of Comparative Zoology at Cambridge.

The relations of the several primary groups of the class may be more readily understood from a glance at the subjoined table, which will also serve as a genealogical table for those who accept the doctrine of evolution. The more generalized forms — and therefore the quasi-eldest — are represented by the left branches. It may not be entirely superfluous to remark that adaptive special modifications must be subordinated to morphological in every case: it will therefore be understood that although the Cetacean is, in a teleological sense, the most specialized form of mammals, it is a divergent from the same common stock as the Carnivores and other Educabilia, and must be contrasted morphologically with them alone and not with the rest of the mammals; the bat, another extremely specialized form, is in like manner a derivative from the same common stock as the Insectivores, and therefore to be contrasted with them alone.




## CLASS MAMMALIA.

Abranchiate Vertebrates with a brain whose cerebral hemispheres are more or less connected (and in nearly inverse ratio) by an anterior com-

missure, and a superior transverse commissure (corpus callosum); the latter more or less roofing in the ventricles: the lungs and heart in the thorax and separated from the abdominal viscera by a muscular diaphragm: aorta single and reflected over the left bronchus: blood with red non-nucleated blood-corpuscles undergoing a complete circulation; entirely received and transmitted by the right half of the quadrilocular heart to the lungs for aeration (and thus warmed), and afterwards returned by the other half through the system. Skull with two condyles, chiefly developed on the exoccipital elements (one on each side of the foramen magnum): with the malleus and incus superadded as specialized auditory ossicles: and the lower jaw (composed of a pair of simple rami) articulated directly by convex condyles with the squamosal bones. Dermal appendages developed as hairs. Viviparous: fœtus developed from a minute egg: young nourished after birth by a fluid (milk) secreted in peculiar glands (mammary) by the mother.

### SUB-CLASS MONODELPHIA.

Brain with the cerebral hemispheres connected by a more or less well-developed corpus callosum composed of a body as well as a folded psalterial portion, and a reduced anterior commissure; with a well developed septum. Sternum with no element in front of the manubrium or presternum. Coracoid not connected with the sternum, but early anchylosed with and developed as a simple process of the scapula. Oviducts debouching into a single vagina. Testes variable in position, but the vasa deferentia open directly or indirectly into a distinct and complete uretha, (and not into a cloacal cavity). Ureters discharge directly into the bladder the renal secretion, which thence passes into the uretha. Mammary glands with well developed nipples. Young retained within the womb till of considerable size and nearly perfect development, and deriving its nourishment from the mother through the intervention of a "placenta" (developed from the allantois) till birth. Scrotum never in front of penis.

## Super-Order Educabilia.

Brain with a relatively large cerebrum, behind overlapping much or all of the cerebellum, and in front much or all of the olfactory lobes; corpus callosum (attypically) continued horizontally backwards to or beyond the vertical of the hippocampal sulcus, developing in front a well-defined recurved rostrum.

### (*EDUCABILIA QUADRIPEDIA.*)

Posterior members and pelvis well developed. Periotic and tympanic bones articulated with the squamosal.

#### (*Primate Series.*)

#### I. ORDER PRIMATES.

Members almost or entirely exserted outside of the common abdominal integument. Digits with corneous appendages developed as claws (i. e.

compressed) or, attypically, as nails (i. e. depressed). First digit (great toe) of hind foot (pes) enlarged, opposable to the others (in man, resuming parallelism with them), always furnished with a nail. Clavicles completely developed. Brain with a well-developed calcarine sulcus, giving rise to a hippocampus minor within the posterior cornu of the ventricle by which the posterior lobe of the cerebrum is traversed. Teeth of three kinds (canines of second set exceptionally atrophied), all encased in enamel; molars rooted. Incisors four in each jaw: etypically, two — or all — in upper jaw suppressed. Placenta deciduate, discoidal.

Contains eight families, representing two sub-orders: ANTHROPOIDEA, with five families, and LEMUROIDEA with three families.

(*Feral Series.*)

## II. ORDER FERÆ.

Legs with the proximal joints (humerus and femur) more or less inclosed in the common abdominal integumen. Digits with corneous appendages developed as claws: first digit of hind foot attypically reduced or atrophied: etypically hypertrophied (e. g. *Pinnipedia*). Clavicles none, or rudimentary. Brain with no calcarine sulcus. Teeth of three kinds, all encased with enamel: canines specialized and robust; molars attypically adapted for carnivorous diet, one $(\frac{\text{P. m.4}}{\text{m. 1}})$ or more in each jaw being sectorial, followed by tubercular ones. Incisors archetypically six in each jaw, exceptionally two or more suppressed. Placenta deciduate, zonary. Scaphoid and lunar consolidated into one bone.

Contains twenty families, representing two sub-orders: CARNIVORA or FISSIPEDIA, with seventeen families, four of which are extinct, and PINNIPEDIA with three families.

(*Ungulate Series.*)

Legs with the proximal joints more or less inclosed in the common abdominal integuments. Digits with corneous appendages developed as hoofs. Clavicles entirely absent. Teeth of three kinds (canines and incisors of second set exceptionally in part undeveloped), all encased in enamel: molars attypically with grinding surfaces. Scaphoid and lunar separate.

## III. ORDER UNGULATA.

Incisors (archetypically $\frac{6}{6}$: often, especially in the upper jaw, reduced in number or wholly suppressed: implanted by simple roots) with incisorial crowns. Feet with inferior (or, rather, posterior) surfaces with a hairy skin continuous with the rest of the integument; carpal bones in two interlocking rows; cuneiform, narrow, and affording a diminished surface of attachment forwards for the ulna (which is retrorse beside the radius); unciform and lunar articulating with each other and interposed between the cuneiform and magnum: hind foot with the astragalus at its anterior portion scarcely deflected inwards, articulating more or less with the cuboid as well as navicular: toes (not more than four — d 2 to d 5 — completely developed) with terminal joints encased in thick hoofs. Placenta non-deciduate (diffuse or cotyledonary).

Contains twenty-nine families, representing two sub-orders; ARTIODACTYLI, with nineteen families, of which eight are extinct, and PERISSODACTYLI with ten families, of which seven are extinct.

### IV. ORDER TOXODONTIA.

Incisors ($\frac{6}{6}$ or $\frac{4}{6}$, variable as to insertion), with incisorial crowns. Feet? carpal bones? hind foot with the astragalus at its anterior portion inclined obliquely inwards, articulating in front only with the navicular; (calcaneum with an extensive upwards surface for the articulation of the fibula, and with a large lateral process articulating in front with the astragalus. Molars of upper jaw, broad and extending into an externo-anterior angle; of lower jaw, narrow and continuous, in a uniform row).

Contains two families, both of which are extinct.

### V. ORDER HYRACOIDEA.

Incisors ($\frac{4}{4}$) of upper jaw next to symphysis (with persistent pulps) long and curved; those of lower jaw straight and normal. Feet with inferior surfaces furnished with pads (as in Rodents and Carnivores): carpal bones in two interlocking rows: cuneiform extending inwards (and articulating with magnum), and affording an enlarged surface of attachment forwards for the ulna (which is antrorsely twisted); unciform and lunar separated by the interposition of the cuneiform and magnum: hind foot with the astragalus at its anterior portion extended, and, as a whole, much deflected inwards, articulating in front only with the navicular; toes (four to the front feet, three to the hind) with terminal phalanges encased in hoofs (inner nail of hind foot curved). Placenta deciduate, zonary.

Contains one family.

### VI. ORDER PROBOSCIDEA.

Incisors ($\frac{2}{0}$, or, in extinct forms, $\frac{2}{2}$ or $\frac{0}{2}$, renewed from persistent pulps,) developed as long tusks curved outwards. Feet with palmar and plantar surfaces invested in extended pad-like integuments, which also underlie the toes: carpal bones in two regular (not interlocking) rows, broad and short; cuneiform extended inwards — broad, and furnishing an enlarged surface of attachment forwards for the ulna (which is antrorsely produced). Unciform directly in front of cuneiform, and magnum directly in front of lunar: hind foot with the astragalus at its anterior portion very short (convex,) and not deflected inwards, articulating in front only with the navicular: toes (five to each foot, in known forms,) encased in broad shallow hoofs. Placenta deciduate, zonary. Snout produced into a very long proboscis. Legs mostly exserted outside the abdominal integument; and with the proximal and succeeding joints extensible in the same line.

Contains two families, one of which is extinct.

## (*EDUCABILIA MUTILATA.*)

### (*Mutilate Series.*)

Posterior members and pelvis more or less completely atrophied; the

form of the body being fish-like, furnished with a horizontal tail, and specialized for progression in the water. Periotic and tympanic bones anchylosed together, but not with the squamosal.

### VII. ORDER SIRENIA.

Brain narrow. Skull with the foramen magnum posterior, directed somewhat downwards: supra-occipital nearly vertical and not extending forwards, the parietals meeting and interposed between it and the frontal. Periotic with a posterior irregularly rounded part; tympanic annuliform. Lower jaw with well-developed ascending rami and normal transverse condyles and coronoid processes. Lateral teeth molar, and adapted to trituration of herbage. Neck moderate; second cervical vertebra with an odontoid process. Anterior members moderately long, flexed at the elbow; with carpal bones and phalanges directly articulated with the adjoining ones; and with normal digits. Mammæ two, pectoral. Heart deeply fissured between the ventricles.

Contains four families one of which is certainly, and another probably, extinct.

### VIII. ORDER CETE.

Brain broad. Skull with the foramen magnum entirely posterior, directed somewhat upwards: supra-occipital very large, sloping forwards, and (attypically) extending forwards over or between the frontals. Periotic attenuated backwards; tympanic solid, entire. Lower jaw with no ascending ramus, with its narrow condyles at the posterior extremities or angles of the rami, and with only rudimentary coronoid processes. Teeth (lateral) conic or compressed. Neck attypically very short; second cervical vertebra with no odontoid process. Anterior members (attypically) abbreviated, extended backwards in a continuous line; with carpal bones and phalanges often separated by cartilage; and with the second digit composed of more than three phalanges. Mammæ two, inguinal.

Contains ten families, representing three sub-orders; ZEUGLODONTIA with two families, both extinct; DENTICETE with six families, one of which is extinct; and MYSTICETE with two families.

## Super-Order Ineducabilia.

Brain with a relatively small cerebrum, leaving behind much of the cerebellum exposed, and in front much of the olfactory lobes: corpus callosum extending more or less obliquely upwards and terminating before the vertical of the hippocampal sulcus, with no well defined rostrum in front.

(*Insectivorous Series.*)

Teeth encased in enamel: incisors (very variable as to number) without persistent pulps: canines present (but sometimes modified in form): molars attypically with pointed cusps. Lower jaw with condyles transverse, received into special condyloid sockets. Placenta discoidal deciduate.

### IX. ORDER CHIROPTERA.

Anterior members adapted for flight: the ulna and radius being united, and the metacarpal bones and phalanges—2d to 5th—much elongated; the whole sustaining a very thin leathery skin arising from the sides of the body, and extending backwards on the hind members, down to their tarsi. Mammæ pectoral.

Contains nine families representing two sub-orders; FRUGIVORA with one family, and INSECTIVORA with eight families.

### X. ORDER INSECTIVORA.

Anterior as well as posterior members adapted for progression on land: the ulna and radius entirely or partly separated: metacarpal bones and phalanges normally developed. Mammæ abdominal.

Contains ten families referable to two sub-orders; DERMAPTERA, with one family, and GRADIENTIA, with nine families, one of which is extinct.

*(Rodent Series.)*

### XI. ORDER GLIRES.

Teeth encased in enamel: incisors ($\frac{2}{2}$; exceptionally, also two supplementary posterior teeth,) continually reproduced from persistent pulps, and growing in a circular direction: canines null: molars attypically with ridged surfaces. Lower jaw with condyles longitudinal, and not received in special condyloid cavities, but gliding freely backwards and forwards. Members and feet ambulatorial. Placenta discoidal deciduate.

Contains sixteen families, representing two sub-orders: SIMPLICIDENTATI, with fourteen families, and DUPLICIDENTATI, with two families.

*(Edentate Series).*

### XII. ORDER BRUTA.

Teeth (when developed) not encased in enamel: incisors typically absent (lateral present in Dasypus): molars variable: members and feet ambulatorial (modified often for grasping and digging). Placenta variable (discoidal deciduate in *Orycteropodidæ* and *Dasypodidæ;* diffuse deciduate in *Manididæ;* and coyledonous non-deciduate? in *Bradypodidæ*).

Contains nine families, representing five sub-orders. VERMILINGUIA, with one family; SQUAMATA, with one family; TODIENTIA, with one family; TORDIGRADA, with two families, one of which is extinct, and DORICATA, with three families, one of which is extinct; also one extinct family of undetermined affinities.

## SUB-CLASS DIDELPHIA.

Brain with the cerebral hemispheres chiefly connected by a well-developed anterior commissure, the corpus callosum being rudimentary, and with a moderately developed septum. Sternum with no element in front of the manubrium. Coracoid not connected with the sternum, but early anchylosed with and developed as a simple process of the scapula. Oviducts debouching into separate vaginas. Testes chiefly abdominal; vasa

deferentia opening into a distinct urethra. Ureters discharge directly into the bladder the renal secretion, which thence passes into the urethra. Mammary glands with well developed nipples. Young born when of very small size and imperfect development; never connected by a placenta with the mother, but attached by her to the nipple when born, from which the milk is forced by herself into the mouth of the young. Scrotum in front of penis.

### XIII. ORDER MARSUPIALIA.

Only order of the sub-class. Contains thirteen families, referable to four sub-orders: RHIZOPHAGA, with one family; SYNDACTYLI, with seven families, two of which are extinct; SARCOPHAGA, with two families; and CHIROPODA with one family; also two extinct families of doubtful affinities.

## SUB-CLASS ORNITHODELPHIA.

Brain with the cerebral hemispheres chiefly connected by a well developed anterior commissure, the corpus callosum being very rudimentary, and with no defined psalterial fibres; with the septum very much reduced in size. (Flower.) Sternum with a peculiar T-shaped bone (the episternum or interclavicle) in advance of the manubrium or presternum. Coracoid extending from the clavicle to the sternum, and only towards maturity anchylosed with the scapula. The oviducts, enlarged below into uterine pouches, but opening separately from one another, as in oviparous vertebrates, debouch, not into a distinct vagina, but into a cloacal chamber, common to the urinary and genital products, and to the fæces. Testes abdominal in position throughout life, and the vasa deferentia open into the cloaca, and not into a distinct urethral passage. Ureters pour the renal secretion, not into the bladder, which is connected with the upper extremity of the cloaca, but into the latter cavity itself. Mammary glands with no distinct nipples. (Huxley.)

### XIV. ORDER MONOTREMATA.

Only order of the sub-class. Contains two families.

## ON THE RELATIONS OF ANOMIA.—BY PROF. EDWARD S. MORSE.

THIS peculiar genus of Lamellibranch mollusks included also Terebratula according to the early writers on the subject. Misled by external characters, Linnæus, Lamarck and others believed these two forms closely related. While not the slightest ground existed for bringing them together, yet the mere fact of these two animals being enclosed within a limy shell composed of two pieces, held to the rock by a process which passed out through that element of the shell which was below, was sufficient proof of their kinship, at least to those who were ready to judge everything

by external characters. The whales among fishes, the barnacles among mollusks, were only some of the many blunders made by this superficial way of comparison. And now after the structure of Brachiopods is well known, and all admit the valves to be dorsal and ventral, while the valves of Anomia are right and left, and after the splendid memoirs of Lacaze-Duthiers on the anatomy of Anomia has shown that the nearest relations are with the oyster and pecten, there are still several zoologists who vaguely imagine that some sort of relationship exists between Terebratula and Anomia. This brief communication is made to settle the question with those who never care to go more than shell deep in the subject, for unfortunately the author had only the empty shells to work upon. It will also verify the statement made by Forbes and Hanley in their standard work on the British Mollusca, where the shelly plug which escapes from the sinus in the flat valve to hold the body to its base of attachment is compared to a byssus. They say "When the very young fry of this genus shall have been carefully observed, we believe they will be found spinning a byssus, which passing through this sinus fixes the shell in the first instance, before a portion of it becomes attached, eventually becomes detached with a part of the adductor muscle and forms the opercular process." Lacaze-Duthiers in his examination of the adult form refers to these statements and expresses his belief in their correctness.

In examining some sea-weed collected by a friend last spring I found a lot of the young of Anomia. In these the sinus was not closed, but open toward the anterior margin. The nucleus presented an elongate oval shell larger behind; the beaks nearer the anterior, and no sign of a perforation. The shape was more like that of Montacuta, and the lines of growth were regular and distinct. On the right valve at its lower margin was seen a slight notch, and the few last incremental lines indicated that the notch was made in the last stages of the nucleus. It can only be conceived that the animal before this was a rover, that it then commenced to fix a byssus, the animal dropping to one side and the notch caused by the lowermost valve growing around it, the other valve showing no signs of this notch. So soon however as the shell rested upon one side a different growth took place, a loose-textured, colorless deposit rapidly formed, the outline becoming gradually circular and the lowermost or right valve growing rapidly

behind and downward, then forward and upward, the byssal attachment soon became enclosed in a wide foramen, this extension ultimately reaching the umbones of the larval shell to which it unites. From these facts it will be seen that it presents not even the remotest resemblance to the Brachiopods, but that the young shell has all the proportions of a Bimyarian, and its affinities may be quite remote from Ostrea or Pecten. A study of the early stages of these last named genera would easily settle all these points.

## On Eozoon Canadense in the Crystalline Limestones of Massachusetts. By L. S. Burbank.

The limestone deposits here referred to, occur in the band of granitic gneiss which extends in a southwesterly direction from near the mouth of the Merrimack river through the entire breadth of the State, and includes the well known mineral localities of Bolton, Boxboro' and Chelmsford.

Soon after the discovery of *Eozoon Canadense* by Mr. Bicknell, in the serpentine limestone of Newbury, it was also identified by Dr. Dawson in specimens collected by me at Chelmsford; as noticed by Dr. Hunt in the "American Journal of Science" for January, 1870. The specimens then examined were not from the rock in place, but were obtained from some outlying masses near one of the quarries. These discoveries led me to make a further examination of several of the old limestone quarries in the same formation. The eozoonal rock was then found in place at several of the quarries, and its position in relation to the other rocks observed.

At all the quarries the limestone has been so thoroughly exhausted, that the limits of its extent at the surface can be readily traced. The relations of the limestone to the enclosing rocks can thus be easily seen.

By the careful study of these relations, and by reference to many specimens collected and facts observed, the following conclusions have been reached.

1. *These limestones are not true stratified rocks laid down with the gneiss, but are subsequent deposits of a vein-like character.* The fact that some of the deposits appear to be interstratified with the gneiss, and also are found along a line apparently coinciding with the strike of the strata, may seem to indicate that

they are parts of original strata included in the gneiss; but their position may also be explained in accordance with another theory, in support of which I shall offer some evidence.

2. *The principal deposits occur along the line of an anticlinal, filling cavities produced by the folding and the falling down of portions of the included strata of the gneiss.* The anticlinal position is most clearly shown at Chelmsford, where there are four veins or masses of the limestone, in two lines coinciding with the strike of the gneiss.

These lines are about half a mile apart, extending in a northeast and southwest direction; the strike, as observed by the compass, being north 65° east. The strata of the gneiss dip in opposite directions from these lines; toward the northwest at an angle of about 65°, to the southeast at an angle varying from about 70° to a nearly vertical position.

The deposits are all of very limited extent, the largest being at the surface not more than two hundred and twenty feet in length, and about sixty feet in width, including the intervening bands of gneiss.

The aggregate length of all the limestone deposits that occur along a line of some twenty-five miles in length, is probably less than one thousand feet.

The vein-like character of the limestone is most plainly shown in one of the abandoned quarries in Chelmsford. The deposits here occur in two principal veins extending in the direction of the strike of the strata to about two hundred feet in length. The structure here plainly shows that cavities which have become filled with the limestone were formed by the folding and faulting of the strata of gneiss. The masses of limestone are separated by strata of gneiss which are also folded and arched over, enclosing cavities filled with the limestone.

At one of the quarries it can be seen that the limestone rested against the irregularly fractured ends of strata of gneiss, which fill a small space in one of the excavations, completely dividing the limestone into two masses.

That the limestone was deposited in cavities mostly closed at the top, which have since been uncovered and exposed at the surface by the denuding action of the drift, seems to me a reasonable deduction from the facts observed.

It is worthy of note that the gneiss of the enclosing walls of

the cavities, and that of the dividing bands and the projecting masses nearly enclosed by the limestone, — is all of the same character with that of the surrounding strata not adjacent to the quarry.

In the direction of the strike of the strata also, at a few yards distance from the quarries, the common rock of the region is found with apparently no traces of calcareous matter. In the line along which most of the quarries occur, there are intervals of several miles where no traces of limestone have been found, though the ledges are exposed at the surface in numerous places.

The central and principal part of the mass which filled the veins and pockets and constituted the bulk of the deposit, was *a coarsely crystalline magnesian limestone, homogeneous in structure and showing no traces of stratification.* In examining numerous specimens of this limestone from the different quarries, I have found in it no traces of the eozoonal structure.

The various silicates which form the large number of distinct minerals for which these localites are noted, occur only *attached to, or near, the enclosing walls of the cavities*, and generally in bands or layers, though sometimes irregularly distributed. They are found generally in pretty regular succession. A network of interlacing crystals of actinolite, with smoky quartz, calcite and phlogopite, may be seen attached to the walls; and passing inward there are found pyroxene, scapolite, apatite, boltonite, fine fibrous tremolite, etc.: and also green serpentine in irregular bands or layers, traversed by narrow seams of chrysotile; or scattered through the rock in irregular rounded grains and masses, with intervening spaces filled with calcite.

In these portions of calcite are found the radiating and branching forms that have been identified and described as belonging to the structure of Eozoon. The granules of serpentine are sometimes arranged quite regularly in concentric lines, but more commonly appear irregularly scattered and varying indefinitely in form and size.

Some of the specimens from Chelmsford show masses of the serpentine intersected by narrow seams of chrysotile, and attached to portions of the rock in which the decalcified spaces show the tubuli in great abundance, *attached to the serpentine grains as if growing out from their surfaces.* Some of the grains are surrounded by a fibrous layer, closely resembling the "true cel]

wall" of Eozoon as I have seen it in the Canadian specimens. The surfaces of many of the grains are covered with acicular crystals penetrating the calcite. Some of these, as they extend into the calcite, become rounded and curved, losing the acicular character.

In nearly all the specimens examined, bundles of acicular fibres, apparently of tremolite, are scattered abundantly in the calcite.

In some portions of the rock the serpentine appears embedded in the limestone in definite crystalline forms, apparently pseudomorphs of chrysolite, or boltonite. In the quarries of Boxboro' and Carlisle, cinnamon garnet is abundant, associated with scapolite and green pyroxene or coccolite, with calcite. I have examined the calcite of many of these specimens for traces of the eozoonal structure, but, so far, with negative results. In fact, so far as I have observed, the tubuli invariably occur in the rock associated with serpentine.

Some facts have been stated in this communication for which I offer no theories in explanation. I do not claim a sufficient knowledge of the Foraminifera to found any argument upon the microscopic appearances that I have observed, nor do I mean now to enter into a discussion of the general question as to the true character of the *Eozoon Canadense*, as described by Carpenter and Dawson.

I am unable, however, to reconcile the facts here stated with the theory that the form in these rocks which have been identified as belonging to the structure of Eozoon, are of organic origin.

On the other hand, it appears to me not unreasonable to infer that the so-called "tubuli" that are so abundant in these rocks, *are semi-crystalline forms that have been deposited with the serpentine and other minerals on the walls of the cavities*, by infiltration of waters charged with mineral matters.

Professor PERRY said:—I desire to bear testimony to the general correctness of the statements made by Mr. Burbank.

In addition to the evidence given by him, I would refer to the fact that the limestones under consideration exactly conform with breaks and other irregularities in the enclosing mass of gneiss. I may also state that in some places calcareous veins which evidently proceeded from the main masses of limestone, may be seen ramifying portions of the walls that form the cavities.

As geologists have generally supposed that all limestones are stratified rocks, a few words may be needful on this point, especially, as serving to

meet the objection in this direction which is likely to occur to many minds. Dr. Emmons, as most no doubt are aware, endeavored to show that limestones occur as intrusive masses as well as in stratified beds. Commencing my study of the limestones connected with the foliated series of rocks in the light of this view, I finally became convinced in 1861, and during the same year set forth in a series of lectures, that some of these limestones have a vein-like structure, and should be regarded as true vein-stones.

Such limestones are to be met with in association with the foliated rocks both of eastern and western Vermont, and in various parts of Massachusetts. They also occur among the Adirondacks. Limestones of this character, hand-specimens of which cannot be distinguished by the naked eye from specimens of stratified Silurian limestones, are likewise found in Vermont and elsewhere in the form of dikes. In most of these cases close examination shows that the dike-like masses were formed in the vein-like way by gradual deposition extending from the enclosing walls toward the centres of what once were cavities. Similar masses of calcareous vein-stone are to be met with in St. Lawrence County, N. Y., and in some other places, penetrating beds of sandstone.

These, and similar cases which might be readily cited, are suited to remove the objection that limestones are always stratified rocks. At the same time the occurrence of undoubted *Eozoon Canadense* in calcareous vein-stones of eastern Massachusetts tends not only to disprove the animal origin of the specimens from the localities under consideration, but also to involve in doubt the organic character of the Eozoon generally.

## On the Eozoon Limestone of Eastern Massachusetts. — By Prof. J. B. Perry.

Having about ten years ago, made out that some of the limestones associated with the foliated rocks in Vermont and New York, are vein-stones, I have ever been skeptical in regard to the supposed organic nature of the Eozoon. As I had more recently satisfied myself that limestones in Stoneham, Newbury, and several other places in eastern Massachusetts are also vein-rocks, I at once, on the announcement of the discovery of Eozoon in the limestones of Newbury, discredited its assumed organic character, on the ground of its occurrence in calcareous masses of a vein-like origin. On hearing of a like discovery in Chelmsford, and seeing a specimen, I had a similar conviction; and this I immediately expressed in one of the lectures which I was then delivering in course, and was able fully to confirm by personal examination, on visiting the quarry a few months later, in company with my friend Mr. Burbank, of Lowell, who had before and has since

devoted himself assiduously to the study of the rocks in his neighborhood.

The limestones in which the so-called Eozoon is found, as should be borne in mind, do not occur in a continuous line, as is usual in stratified rocks. They are isolated masses, often having a lenticular shape, and are found only at irregular intervals. Those at Chelmsford occupy, or rather occupied (for they have been largely removed) cavities, or oven-shaped spaces, formed by the disturbance of the overlying gneiss. In places, the gneiss now so overarches some of the cavities, and it evidently once so overarched them all, as to make it impossible that fossils, or any other solid foreign bodies, could have been carried in and deposited in a continuous series, beneath the summits and all along the sides of the arches.

Again, these calcareous masses have that banded structure which is peculiar to veins. There is, moreover, connected with this structure a succession of minerals, showing that the deposition must have taken place gradually, one layer succeeding another from the sides of the cavities toward the centres, until the central spaces were finally filled. Once more, these layers exactly conform with the most abrupt irregularities of the enclosing gneiss, while portions of the limestone in given instances clearly ramify, in a vein-like way, the walls which form the cavities.

Such are some of the points characteristic of these calcareous vein-stones. That the limestones of Chelmsford have truly a vein-like structure should be evident from what has been said, and especially, from an examination of the same and of similar rocks as they occur in place. The question as to their origin, whether by infiltration, segregation, or sublimation, I leave undiscussed for the present.

Now it is a fact, that genuine Eozoon — Eozoon which is recognized as genuine by those who hold to its organic nature — actually occurs in these limestones.

Thus, an enigma is asking for solution — an enigma involving difficulties not easily answered, and imposing a task not readily performed, in consistency with the commonly received views of this strange fossil form. Indeed, the fact that genuine Eozoon occurs in these calcareous vein-stones, under the conditions indicated, raises an important question which I leave those conversant with Eozoon structure to solve as best they are able. While it in-

dicates that the so-called Eozoon of Chelmsford is not of animal origin, it at the same time casts discredit upon the organic character of the "Eozoon" generally, and fixes the burden of proof upon its advocates. It also certainly suggests that the resemblance which the "Eozoon" has to animal structure is, like that of Dendrites to vegetable forms, merely the result of chemical agency.

REMARKS ON THE GEOLOGICAL MAP AND SECTION OF THE ROCKS OF MISSOURI.— BY PROF. G. C. SWALLOW.

IT was his object to put on record some of the general results of the Geological Survey of Missouri made by himself and his able assistants (one of whom, Dr. B. F. Shumard, is now dead.) Since the interruption of the survey by the late civil war there has been no opportunity offered for the publication of the results.

The survey was most minute and carefully made, and the results the same as represented by the section and map before us. The boundaries of the formation save in eight or thirteen counties are accurate and all the formations are as delineated by the section running through all the great systems known to American geology.

Some of the results in Economical Geology were mentioned.

There are twenty-seven thousand square miles of Coal Measures containing at least twenty coal beds, one at least of the block coal. Large deposits of specular, hæmatite, bay and spathic ores were mentioned. The mineral regions containing mines of lead, zinc, cobalt, nickel and copper cover an area of about eight thousand square miles; all but two hundred square miles in the Magnesian Limestone series (of the Potsdam and Calciferous ages) and two hundred square miles at Granly in the lower Carboniferous rocks. Lead and zinc often cut the coal beds in their vertical veins.

The Potsdam Sandstone rests nonconformably upon the Azoic stratified slates of Pilot Knob. Hence Pilot Knob.

Prof. E. W. HILGARD inquired of Prof. Swallow whether the chalky siliceous beds in southeastern Missouri, conjectured to be of cretaceous age, did not occasionally contain grains of glauconite, black sand and obscure casts of shells.

Upon Prof. Swallow replying in the affirmative, Prof. HILGARD stated that while such materials were altogether foreign to the Cretaceous beds of the adjoining states of Arkansas, Tennessee and Mississippi, a narrow

belt of precisely such deposits frequently bordered the lignitic Tertiary of the two latter states. Occasionally, they expand into larger outliers and exhibit the lithological character and fossils of the Buhr-stone group, the lowest of the marine Eocenes which he considers as the equivalent in time, of the lignitic beds of Tennessee, Arkansas and North Mississippi.

## The Great Mound on the Etawah River, near Cartersville, Georgia.—By Col. Charles Whittlesey.

This mound is situated on the river bottom, on the north bank, about three miles below where the railroad from Chattanooga to Atlanta crosses the Etawah river. Its base is an irregular figure, five hundred and eighty-five poles in circumference, covering about three acres. The bottom on which it stands is elevated eighteen to twenty-three feet above low water, and is seldon invaded by high water in any part. The mound is truncated, nearly flat on the top, which embraces about an acre of ground. This area is elevated fifty feet above the base, and seventy-three feet above low water. There is no high land within a quarter of a mile on either side of the river. Its slopes are very perfect and steep. Bushes, grass, vines, shrubs and trees grow luxuriantly on its sides and the level space on the top is annually planted in corn or cotton. There is a broad ramp or road fifty feet wide, commencing at the southeast corner which winds around the southerly face bending to the right, and reaches the summit on the west side. It has an easy grade for footmen and horses, but is too steep for vehicles. The mass of this mound I estimate at about one hundred and twenty thousand cubic yards, or about four-fifths of the contents of the British earth pyramid raised on the field of Waterloo. Rising over the alluvial valley where it is isolated it has an impressive aspect, like that of the pyramids of Egypt on a sandy desert. This valley, however, is everywhere rich and beautiful.

Like some of the larger pyramids it has two smaller ones which appear to be tenders. One is a square, truncated pyramid which stands one hundred feet east of the foot of the ramp and is twenty-two feet high, its flat top being about eighty feet on a side; its slopes, steep and perfect like the great mound. To this one there is no ramp or place of ascent.

The other is about one hundred feet due south of the southwest corner of the great mound, and is of about the same dimensions

but has on its east side a ramp or graded way by which to ascend to the flat space on the top. Its sides and that of the other tender are from five to ten degrees west of the magnetic meridian.

All of this group are composed of the rich black alluvial earth of the adjacent bottom, with occasional lumps of red clay which constitutes the base of the river terraces that border the valley. About two hundred yards from the mounds on the north there are the remains of a ditch which has been mostly obliterated by cultivation and which encircles the group in a circular form a distance of about one-fourth of a mile, coming to the river below but not above. Within and without the trace of this ditch which the owner says had an interior embankment, there are low mounds partly plowed down. Near its upper or the easterly end, there are two large, oblong pits from which a part of the earth of the mounds may have been taken.

There are other small mounds in the valley below on both sides of the river. The valley is bordered by limestone bluffs about two miles apart which rise two hundred to two hundred and fifty feet above the river. On a rocky summit about two miles west of the great mound is what is called the "Stone Fort." It consists of a wall or heap of loose blocks of limestone surrounding the summit in an oval form, the largest diameter of the enclosure being two hundred and twenty poles. There are numerous openings in it at irregular intervals, some of them fifty feet broad. The space around the crown of the hill is clear of loose stones and this explains the existence of the wall, which has the appearance of a stone fence fallen down.

It does not have the appearance of a fort or stronghold, but of a high place dedicated to imposing ceremonies to which the people came up in all directions through the openings or passes in the line of stones. Probably, it was then as now covered with oaks. The crown of the hill is about fifty feet above the encircling wall, and presents from its summit a view of the valley and the country opposite that is hardly equalled for scenic beauty.

It is probably the work of the red man of our times and has no connection with the great mound or its builders.

Professor W. C. KERR said there is a mound quite similar to the one just described by Col. Whittlesey, in the valley of the Tennessee river, in Macon County, N. C., with sides equally steep, and outlines equally well preserved, of its use, date of construction, or its builders there

exists no tradition in the region. Its form is the frustum of a cone, whose base is about seventy-five feet in diameter, and top about fifty, and its height thirty or forty feet. It stands on the alluvial river-bottom, and was doubtless built of the same material, although all signs of excavation for this purpose have been entirely obliterated by subsequent deposition. On digging into this pile, nothing was found which could throw any light on its history.

Prof. G. C. SWALLOW remarked that Hon. Godfrey Lesceur, grandson of the first Spanish commandant at North Madrid, Mexico, says the old Indians had a curious tradition respecting the mound builders. They said: "We did not build the mounds, we came to this (Mississippi) valley from the northwest. Here we found a quiet, peaceable people cultivating the soil and living in communities, and having mounds for the Great Spirit and burial. They begged us to leave them, as there was country to the northeast. We went, but found the country poorer, and after a time returned and drove out the mound builders, who went to the southwest. We burnt their wigwams and possessed the country." He remarked that no warlike implements had been found with the real mound builders, and there is ample evidence that their temples were destroyed by fire; at least those in North Madrid, Mexico, as remains of the charred wood-work still exist in the mounds.

ANCIENT ROCK INSCRIPTIONS IN OHIO. — BY COL. C. WHITTLESEY.

SEVERAL diagrams were presented to the section representing rock sculptures in Ohio, that are presumed to be ancient and to have some significance. The largest is a tracing made by Dr. J. H. Salisbury, of Cleveland, with the assistance of Mrs. Salisbury, from a mural face of conglomerate, near the famous "Black Hand" in Licking County, O. Once there was a space of ten or twelve feet in height, by fifty or sixty feet in length, covered by these inscriptions. Most of them have been obliterated by the recent white settlers.

In 1861, Dr. Salisbury took copies from a space about eight by fifteen feet, by laying a piece of coarse muslin over them, and tracing such as remain uninjured, life-size, on the cloth. In this space there are found to be twenty-three characters, most of which are the arrow-head or bird-track character. These are all cut on the edge of the strata, presenting a face nearly vertical, but a little shelving outward, so as to be sheltered by the weather.

Another copy of the remnants of similar inscriptions was taken by Col. Whittlesey and Mr. J. B. Comstock, in 1869, from the "Turkey Foot Rock," at the rapids of the Maumee, near Perrys-

burg. These are on a block of limestone, and in the course of the twenty-five past years have been nearly destroyed by the hand of man. What is left was taken by a tracing of the size of nature.

On the surface of a quarry of grindstone grit at Independence, Cuyahoga County, Ohio, a large inscribed surface was uncovered in 1854. Mr. B. Wood, Deacon Bicknell, and other citizens of Independence, secured a block about six feet by four, and built it into the north wall of a stone church they were then building. Col. Whittlesey presented a reduced sketch, one-fourth size of nature, taken by Dr. Salisbury and Dr. J. M. Lewis, in 1869, which was made perfect by the assistance of a photographer. Some of the figures sculptured on this slab are cut an inch to an inch and a half in the rock, and they were covered by soil a foot to eighteen inches in thickness, on which large trees were growing. Like all of the others they were made by a sharp-pointed tool like a pick, but as yet no such tool has been found among the relics of the mound-builders or of the Indians. The figures are very curious. Among them is something like a trident, or fish-spear, a serpent, a human hand, and a number of track-like figures, which the people call buffalo-tracks, but Dr. Salisbury regards as a closer representation of a human foot covered by a shoe-pack or moccasin. Another figure somewhat resembles the section of a bell with its clapper.

Near the west line of Belmont County, Ohio, Mr. James W. Ward, then of Cincinnati, now of New York, in 1859, took a sketch of two large isolated sandstone rocks, on which are groups of figures similar to those already noticed. Here are the bird-track characters, the serpent, the moccasin or buffalo-tracks, and some anomalous figures. These are plainly cut, with a pick, into the surface of the rock, which, like the Independence stone, is substantially imperishable. Here we have also the representation of the human foot, and the foot of a bear. Another figure, which appears to be the foot of some animal with four clumpy toes, Professor Cope thinks may be the foretrack of a Menopome. One peculiarity of these sculptured human feet is, a monstrously enlarged great-toe joint, even greater than is produced by the modern process of shoe-pinching. This has been observed in other ancient carvings of the human foot upon the rocks near St. Louis, Missouri. These feet range in size from seven to fifteen inches in length. Of all these representations, the bear's foot is closest to

nature. The bird-track, so called, presents six varieties, none of which are anatomically correct. The human hand is more perfect than the foot.

Dr. Salisbury finds, on comparison of these symbolical figures with the Oriental sign-writing, or hieroglyphical alphabets, that there are many characters in common. Some 800 years before Christ, the Chinese had a bird-track character in their syllable alphabet. The serpent is a symbol so common among the early nations, and has a significance so various, that very little use can be made of it in the comparison.

These inscriptions differ materially from those made by the modern red man. He is unable to read that class of them which appears to be ancient.

Lieut. Whipple has mentioned in the "Government Report on the Pacific Rail Road Surveys," an instance of the bird-track character inscribed upon the rocks of Arizona. Professor Kerr, of North Carolina, states that he has noticed similar characters cut in the rocks of one of the passes of the Black Mountains, at the head of the Tennessee river.

These facts indicate wide-spread universality in the use of this style of inscription, and it indicates something higher than the present symbolical, or picture writing of the North American Indians.

Professor W. C. KERR said it may be a matter of some interest in this connection to state that on a recent tour among the mountains of North Carolina, I found, at the foot of the Black Mountain, at an elevation of some 2800 feet, in a gap which was doubtless traversed by an Indian trail, a slab of chloritic rock, about six feet by three and a half, which is covered all over with carvings, representing the tracks of the animals which formerly inhabited the region. Among these I took note of the following: the bear (one track being larger than any specimen known to the modern hunter), buffalo, elk, deer, panther, wolf, fox, rabbit, turkey and snake. There is a second slab of smaller size, at a little distance, with similar markings. These foot-prints are very distinct, and readily identified, although, doubtless, the lines are not so sharp as when first cut.

Professor COPE remarked that one of the representations on the diagram had a close resemblance to the hind foot of the Menopoma or water-dog. He also remarked that what had been regarded by some archeologists as a representation of the head of the mammoth, found in Central America, and which had been brought forward as proof of the contemporaneous existence of man and that now extinct animal, was in fact but a rude figure of a human head.

Colonel WHITTLESEY stated that the representations of Central American sculptures that he had seen were unquestionably elephantine in their character, and could not be tortured into an outline of anything human. He could not say, however, how true to the originals the copies were.

WESTERN COAL MEASURES AND INDIANA COAL.—BY PROFESSOR E. T. COX.

THE study which I have given to the geology of the West, has led me to conclude that the Carboniferous rocks embracing the coal beds, both of the Appalachian and Western coal fields, were formed in two great depressions that gave rise to large inland seas. These seas communicated on the south and west with the ocean, which then extended far up the Mississippi valley and covered most of the southern states as far north as the thirty-fifth parallel.

A high ridge or plateau of Silurian rocks, capped in places with the Devonian, and lying in a northeasterly direction across the states of Tennessee and Kentucky, and along the western border of Ohio and the eastern border of Indiana, separated these two seas from each other, and spreading out over the northern portion of the two latter states, extended into Pennsylvania on the east, and Illinois and Iowa on the west, forming an almost unbroken chain along their northern shores.

In these seas were formed the Sub-carboniferous rocks, and, as the water became shallow from the accumulated sedementary material that went to build them up, a barrier was formed, which shut out the ocean and cut off the source of salt water supply. Facilitated, also, by the drainage from a large surface area, the waters of these seas became less and less brackish, and the conditions necessary for the accumulation of the coal vegetation were, in this way, brought about so gradually that many marine forms of life continued to exist and by degrees accommodated themselves to the new condition of things.

That marine forms of life are brought to adapt themselves to fresh water habitudes, under favorable conditions, has been shown by the researches of Dr. William Stimpson, who found by deep dredgings in Lake Michigan, species of marine crustacea in great abundance; and similar discoveries had previously been made of marine forms of life by dredging in the large fresh water lakes of Europe.

From this, we may readily infer that the North American lakes communicated at one time with the ocean, and that their fauna and flora, were to a certain extent brought to accommodate themselves to the gradual change from salt to fresh water.

The position of the oceans, relative to the land, and the great preponderance of water on the American continent, during the Carboniferous epoch, must have had a decided influence in modifying the temperature and increasing the humidity of the atmosphere, thereby rendering it in every way adapted to the luxuriant growth of the tropical plants which furnished the carbon so providentially stored away in the fossil fuel, for we find that many of these coal producing plants, whose dwarfed prototypes are now confined to the tropics, flourished then as far north as the arctic zone.

There could have been no necessity for any increase of carbonic acid or other material change, as some have supposed, in the composition of the atmosphere beyond a slight increase in its humidity, and the probability is that none existed.

The two great coal fields being separated from each other from the very beginning, as I have endeavored to show, by a barrier of rocks, which present no evidence of any subsequent submergence, and which long antedate the carboniferous era, renders it difficult to comprehend how an equivalency in the coal beds of the Appalachian field, can be found in those of the West, as many of our eminent geologists have maintained.

It is true that the fluctuations in level which served to build up the various strata, may have been, and in all probability were, synchronous over the two basins, but the special requirements for the production of coal beds could hardly have proved uniform over districts so widely separated.

Though once a firm believer in the equivalency of coal seams throughout the Western coal measures, I have seen much of late to shake my faith in the possibility of determining an entire agreement in the coal beds, even in the limited area of the coal fields of Indiana.

From a marked irregularity in the thickness of the Carboniferous beds over any great extent of territory, we have good reason to believe that these inland seas, like all other great bodies of water, were of unequal depth, and consequently, did not present at all times, over their entire area, the conditions

alike favorable for the formation of coal, and that, while the ocean was excluded from the Appalachian sea, where the material for coal beds was forming. The sea on the Western side was still filled with salt water, where the sediment was accumulating which was subsequently changed to rock, and the conditions favorable to the production of coal had not yet been reached. Such a state of things will serve to account for the great discrepancy in the aggregate thickness of the strata in the two coal fields. The Appalachian, being estimated at twenty-five hundred or three thousand feet, whereas, in the Western coal field, the greatest depth will hardly exceed one thousand feet; and in Indiana, not more than seven hundred feet, if so much; though we include, in the latter estimate, every stratum from the Archimedes limestone upward.

From observations made in the Western coal field, during the past three years, extending over portions of southern Illinois, western Kentucky, and Indiana, so many errors have been found in the sections of the coal strata given in the third Kentucky Report, and which were pretty generally copied by other geologists in more recent reports, that I have found it necessary to make an entirely new classification of the coals in the west.

In the connected section of the Western coal beds, given at pages 18–24, 3d vol. Ky. Report, the measures are divided into upper and lower coal measures, and this arrangement, with some local modifications, has, until recently, been generally adopted by geologists. Now, so far as my observations go, either in Kentucky, Illinois or Indiana, I can find neither lithological nor palæontological evidence which can be relied upon for cutting up the Western coal measures into separate epochs. The Anvil Rock sandstone, which was brought into requisition for this purpose, can hardly be depended upon as a horizon, beyond the small district in which it was first discovered, and the equivalency of the Mahoning sandstone of the Pennsylvania geologists, as designated by Owen and Lesquereux, has also proved totally unreliable as a basis for division, even though it should be found necessary to establish one.

In the 3d vol. Ky. Report, and in the Report of a Geological Reconnoisance of Indiana, 1859, the latter stone is at one place referred to the horizon of the Anvil Rock sandstone, and at another locality to that of the Millstone grit.

Indeed, so unfortunate has been the effort to transplant the Mahoning sandstone of Pennsylvania into our western coal measures.

that I can recall no prominent locality where it is distinctly referable to one or the other of the above sandstones. For the equivalency of sandstones in the Western coal field I have, as yet, been unable to find any lithological or palæontological evidence which can be relied upon as a guide to identity.

In the Indiana Report by Prof. Richard Owen, 1859–60, Prof. Lesquereux refers, from palæontological evidence, the sandstone above the "Knob" coal in Spencer county, to the Mahoning sandstone, and appears undecided, whether the position of the "Martha Washington" sandstone, which forms the bluff at Rockport and presents a vertical face of thirty to fifty feet on the side fronting the river, should be referred to the Mahoning or the sandstone above coal No. 2 of his general section given at pages 299–305, (column No. 1 of diagram). At these localities, from my own examinations, I find the Rockport Sandstones to be the Millstone grit, and the "Knob" coal to be coal L of my general section of the coals in Clay county (column No. 3 of the diagram). Consequently, the sandstone which overlies it, in the hill, if referred at all to an equivalency in the Kentucky section, will be at least about the place of the Anvil Rock sandstone.

At Washington, in Daviess county, Mr. Lesquereux found a paucity of palæontological evidence, nevertheless it was believed to be sufficient to warrant him in referring the main coal of that place to No. 1, B, of his section. In his account of the measures, in Daviess county, no mention is made of the heavy bed of sandstone, two miles northeast of Washington, which is overlaid by the "Washington Coal" which he refers to No. 1, B. This sandstone is quite a marked feature in the geology of this part of Daviess county and is underlaid by two workable beds of coal—the upper three feet thick, and the lower three to six feet thick; the space between the two, varying from twenty to forty feet. The lower coal has usually a limestone over it; and being the second coal, in the descending order, below the "Washington coal" is represented as K in my section. A coal fourteen miles north of Washington, overlaid by limestone, is, from its position, referred by him to coal No. 1, C. I suppose the coal in the bed of the river below Edwardsport, in Knox county, is the seam here referred to; if so, it is the second seam below the "Washington coal." Now the "Washington coal" is at least as high up in the measures as coal L of my section. The first coal below L, in

Daviess county, was not recognized in Clay county, and at the time of making my section it was thought that no coal would be found intervening between L and K, consequently, I am now compelled to make an interpolation of a letter and provisionally designate this coal as X; the coal, with the limestone above it, as K, and the five foot coal bed near the top of the hill at Edwardsport, which is equivalent to the "Washington coal" as L.

Passing on northward into Clay county, coal I, of my section, refers to No. 1, A, and K to No. 1, C, of Lesquereux' section.

Now it is clearly demonstrated in this county that there are two workable block coal beds in a space of fifty to sixty feet below the seam reported by Mr. Lesquereux as No. 1, A, or the lowest workable seam.

At Garlick and Collins' mine, on Otter creek, in Clay county, coal K is seen in the side of the hill in the road cut; I, is worked by a drift, and G is worked by a shaft sunk at the foot of the hill on the bank of Otter creek. Both I and G are here loaded in the cars from the same coal tip.

In my first report, 1869, I pointed out the existence of a second workable seam of block coal below the seam then generally worked; its position in the column was determined from imperfect outcrops, and for a time, an error was committed in confounding it with a still lower seam F. Previous to my survey of Clay county, no other person who had examined the ground, dreamed of finding another workable bed of coal below what was called the "Brazil seam" (I). On the contrary, it was universally believed that the strata at Brazil, indicated the latter seam to be the lowest workable coal in the coal measures proper, and, consequently, that no seam of any economical value could be found below it. Since the publication of my first report, the second seam has been reached by shafts and worked at a number of localities in the county, and the existence of the third seam is fully proved by bores.

At Highland, two miles west of Brazil, L of my column, is the principal coal worked, and probably the only seam in the basin, at that locality, which is of a suitable thickness to be mined with profit.

Notwithstanding the high position which it undoubtedly occupies in the measures, we find that it is referred by Mr. Lesquereux to No. 4 of his column, the same seam at Williams' to No. 3, and the sandstone which is seen above the coal at Highland he refers,

without doubt, to the Mahoning sandstone. In fact, the misplacing of coal seams, and confounding of sandstones at all levels with the Mahoning sandstone, of Pennsylvania, and the Anvil Rock sandstone of Kentucky, I might continue to trace throughout the entire coal field of Kentucky, Indiana and Illinois. In the Kentucky reports, and the Report of a Geological Reconnoissance of Indiana, 1859, as well as in the reports of other geologists, who have written on the western coal measures, the distinguished authors appear to have satisfied themselves that the western coal beds and sandstones are synchronous with the Appalachian strata, and that the Mahoning sandstone, there a conspicuous horizon, must, as a matter of necessity, have a place in the western field, and divide here, as there, the measures into upper and lower coal measures, and that the coal beds should conform thereto.

Having pointed out a few of the errors committed in the stratigraphy of the Indiana coals, at localities where their position can be proved beyond a doubt, I will now proceed to show some of the errors that exist in the Kentucky column, from observations made at the same localities that furnished the data upon which it was constructed, and which column has heretofore served as a basis for the arrangement of the coal beds and sandstones of all other districts in the west.

The column of the coal measures given at pages 18–24, 3d vol., Geology of Kentucky, presents us with thirteen hundred and fifty feet of strata, above the Millstone grit or Careyville conglomerate. From the sandstone under coal No. 18, down to the Anvil Rock sandstone, there is a repetition of the strata, including the latter rock, probably as far down as No. 7. This part of the column was constructed from bores that started on the Carthage limestone, which, in Union county, Kentucky, is, I now believe, the equivalent of the limestone over coal No. 11. Though the details of strata passed through in these bores can hardly be relied upon, and in no two instances do they fully agree, as to the character of the rocks, still the place of the coals, and probably their full thickness, is given with considerable accuracy. Therefore, in the arrangement of this part of the column, it was erroneously assumed that the bottom of the lowest bore in Union county, starting from the horizon of the Carthage limestone, stopped just before reaching coal No. 11. From No. 17 down to No. 13 by ref-

erence to the diagram you will observe the close agreement in the spaces between the coals above, and those below No. 11. In the former, they are thirty-five, one hundred and two, one hundred and fifteen, and seventy-seven feet respectively, while in the latter they are forty-six, sixty-seven, eighty-six and one hundred and twenty-seven feet; the aggregate distance from No. 17 to No. 13 being three hundred and twenty-nine feet, and from No. 11 to No. 6, three hundred and twenty-six feet. In giving the space from No. 8 to No. 6, I have omitted No. 7, which, at best, is but a streak of coal, and has no existence in Union county, where the principal data for the section was obtained. We are thus carried down to about the place of the "little coal" at Mulford's, now Shotwell's mines, or No. 6 of the Kentucky column.

From No. 5, passing down, there is but one thin coal seam in the space intervening between it and Bell's coal or No. 1, B.

The Curlew sandstone that is referred to a horizon just below the Mahoning sandstone of Pennsylvania, is the equivalent of the Anvil Rock sandstone. No. 4 coal is No. 11, and No. 3 is the equivalent of No. 1, B, or Bell's coal, which lies just above the Millstone grit or Caseyville conglomerate. In Union county, Kentucky, there is a thin coal in the conglomerate below Bell's coal, but there appears to be no workable seam.

The total thickness of the strata in the Kentucky column, exclusive of the Millstone grit, is thirteen hundred and fifty feet; now strip it of the above errors of repeated strata, and we have, as the depth of the Carboniferous rocks in Union county, Kentucky, only six hundred and twelve feet, including the Millstone grit.

The above errors are, in a great measure, to be attributed to too great a reliance on palæontological evidence, and to an apparent desire to make the measures conform to the Pennsylvania sections of the Appalachian coal field.

Though there are some striking analogies, so far as relates to the character and peculiar arrangement of their accompanying rocks, which were first pointed out by myself in a lecture on the western coals in 1857, between the Pittsburgh seam of Pennsylvania, and the mammoth seam of western measures (No. 11 of Owen's, and which may prove to be K of my column), yet, from the undoubted disconnection of the two fields while the coals were being formed, it is difficult to conceive how any reliable equivalency can be established.

More especially are we led to doubt the equivalency; if we take into account the great preponderance of coal measure strata in the Pennsylvania district, which goes to show that the conditions necessary for the production of coal extended over a much greater period of time in the Appalachian, than in the western field.

Though I have assumed that the greatest depth of coal strata in the western measures will not exceed one thousand feet, in Indiana it will not be found greater than six hundred and fifty feet, including the Millstone grit. In a few localities in this State there are one or more very thin seams of coal below the Archimedes limestone, but no coal of any economical value has yet been found lower than the base of the Millstone grit.

There are in Indiana two well defined zones of coal, the eastern and western zone, and though an equivalency in some of the seams is clearly traced, from one to the other, yet the quality of the coal is quite distinct in each.

The area of the eastern zone is about four hundred and fifty square miles, or two hundred and eighty-eight thousand acres, and the included coals belong to the bituminous variety characterized as *non-caking* or *free-burning*.

The *cherry-coal* or *soft coal* of England is a non-caking coal, but the non-caking coals of Indiana differ somewhat in physical structure from the English coal and from a similar class of coals found in the Mahoning valley, Ohio, and the Shenango valley, Pennsylvania; the latter two being the only other localities in the United States where non-caking coal is formed in any quantity. The Indiana coal from this zone has received the local name of *Block coal;* a name given to it by the miners on account of the facility with which it can be mined in blocks as large as it is possible to handle. The beds are crossed nearly at right angles by joint seams that greatly facilitate the operation of mining, which is usually carried on without resort to blasting. Blocks are taken out the full depth of the seam and leave a zigzag, notched outline, on the face of the mine, resembling a Virginia worm fence.

Block coal has a laminated structure and is composed of alternate thin layers of vitreous, dull black coal, and fibrous, mineral charcoal. In the direction of the bedding lines it splits readily into thin sheets like a slate, but breaks with difficulty in the opposite direction, and when struck with a hammer emits a sound

like that given by wood. Chemically it does not appear to differ from the caking-coals, but in burning behaves quite differently. Unlike the latter, it does not swell and shoot out jets of gas, nor form a cake by running together, neither does it leave an ash mixed with clinker, but retains its shape like hickory wood, until entirely consumed to a small quantity of white ash, which contains no trace of clinker. I have not yet had time to make an ultimate analysis of the block coal, but I believe that, when so examined, its superior heating properties which have been determined in practice by actual work done, though mainly due to its physical structure, will be found partly owing to its containing less oxygen and relatively more hydrogen than is commonly found in bituminous coals. The block coal, in a great majority of the mines that have been opened, is remarkably free from sulphur and phosphorus.

A specimen, taken from Garlick and Collins' new shaft, coal G of my section and which has a specific gravity of 1.232, gave in one hundred parts: Water, 2.10, Gas, 37.35, Fixed Carbon, 57-95, Ash, white, 2.40, Phosphorus, 0.22, Sulphur, 0.073.

At the White River Valley Rolling Mills, in this city, I was informed by the Superintendent, Mr. Sims, an experienced iron master from Pittsburgh, Pa., that it not only required a less quantity of block coal than of any of the coals in use around Pittsburgh to make a ton of wrought iron, but that they were likewise enabled to bring off the heats in a much shorter space of time, and the resulting iron is of a superior quality—three important advantages that cannot be overlooked by iron-masters; and it must be conceded, that the good behavior of a coal in the puddling furnace is one of the very best tests of purity and effective heating properties to which it can be subjected; for, here, its good qualities are brought into requisition, and the bad ones are soon made manifest in the poor quality of the iron produced.

Though the Blast furnaces of Clay county cannot be looked upon as filling all the requisites of an iron furnace best adapted to the use of block coal, still they are enabled to make a ton of No. 1 foundry iron that will, in quality, compare favorably with charcoal iron, by the use of less than two tons of coal; and I feel fully satisfied that by materially increasing the width of these furnaces across the bushes, and raising the temperature of the blast to 1200°–1500°, the *make* will be greatly increased and the consumption of coal very much reduced.

In the Block-coal zone of the Indiana coal field, there are as many as eight seams of non-caking coal, four of which are of good workable thickness over a portion of the field. These are I, G, F and A, which, together, have a maximum thickness of fifteen feet, and by including the other four seams, we have six feet more, making a total of twenty-one feet of block coal.

The superior excellence of the block coal for smelting, and working iron and steel, in all the varied departments of their manufacture, has been fully established by practical tests. Pig iron made with this coal is in every respect equal to charcoal iron made from the same ores; it is a soft gray iron of a highly crystalline structure, contains a large percentage of combined carbon, with but a mere trace of sulphur and phosphorus; properties which render it admirably adapted to the manufacture of Bessemer steel.

For steam and household purposes it likewise has an unrivalled reputation. It burns under boilers with a full and uniform flame that spreads evenly over the exposed surface, thus securing a more uniform expansion of the boiler plates and greater freedom from leaks that are so common when caking coals are used. No clinkers are formed, and owing to its freedom from sulphur it has but little detrimental effect upon the boilers, grates or fire boxes.

The western zone of coals in Indiana comprises by far the greatest area of measures, being somewhat over six thousand square miles, and contains three or more very thick beds of coal, besides a number that are too thin for working. Its eastern boundary, which is formed by the zone of block coal, is irregular in outline, and with my present knowledge of the geology of the country, it cannot be well defined. It is evident, however, that the block coal beds, as we go west, are changed in character and pass into caking coal. The lower members thin out, and are no longer of workable thickness, even before reaching the Wabash river. Of this we have abundant proof by the three deep bores at Terre Haute.

These bores commence about forty feet above low water of the Wabash river, and after passing a few feet of alluvium deposit, were in strata of gravel, sand and hard pan, peculiar to the drift epoch, for a depth of about one hundred and fifty feet, and though they penetrate the Silurian rocks, the records show that but five seams of coal were passed; only the top one being of workable thickness, while the lowest is but two hundred and ninety-three and three-quarters feet below the surface.

Two and a half miles east of Terre Haute, coal N, which is worked by a shaft at Seebyville, crops out; this indicates a rise of the strata to the west, and, as a still further means of accounting for the absence of the upper part of the coal measures in these bores, it is possible that the great bed of drift which is found on the east bank of the Wabash river, at Terre Haute, filled up a ravine or valley from which some of the upper coal beds were removed by abrading forces.

On the west bank of the river, coal L is mined in a number of places from shafts, thirty to fifty feet deep.

From the foregoing data, therefore, I am enabled to correct the error into which I fell in my First Report, 1869, of making the top coal in the Terre Haute bores, coal L., and now place it at least as far down as coal I.

Though from the records that were kept of these bores, it is difficult to point out the base of the coal measures, or that of the Millstone grit, with any degree of accuracy, it is, nevertheless, my opinion, that the latter epoch commenced at about the depth of five hundred feet.

This thinning out of the coal seams as we go west towards the centre of the basin, is a remarkable feature which I first pointed out in 1867. A few miles west of the Indiana line in Clark county, Illinois, bores have been made in searching for petroleum, to the depth of eight hundred feet, without passing a single workable seam of coal, and the two or three thin seams reported, in some of these bores, are in the upper part of the measures.

Judged by the dip of the coal on both sides of the river, the Wabash runs on a slight anticlinal axis, and I believe this to be the case from Attica, in Fountain county, to its mouth in Posey county, and that along its course it cuts through the same strata of rocks, from the bluffs at Merom to its confluence with the Ohio river.

Near the eastern boundary of the zone of caking coals, in Indiana, we find K and L, and sometimes N, of good, workable thickness, averaging from four to eight feet, and in one locality at Pike county, there is a bed not yet studied, but thought to be K, that attains to the thickness of ten feet or more. Taken all together, the maximum thickness of these beds may be estimated at twenty feet, and will yield an average, over the greater part of the district, of ten feet of coal. At some localities the caking coal is of

inferior quality, and largely contaminated with pyrites, which is so generally disseminated through the seam that it is impracticable, in mining, to entirely separate it from the coal. In many of the counties, however, within this zone, the caking coals will compare very favorably with the caking coals of the Pittsburgh, Pa., district.

From her geographical position, and more especially on account of the extent and value of her coal beds, and the peculiar adaptation of this coal to the metallurgy of iron and steel which now forms one of the leading industries of the world, we can safely predict for Indiana a bright future as a manufacturing state. The commerce of the new far west, which is increasing with a rapidity unprecedented in the growth of empires, will just as naturally look to Indiana for its supply of iron and steel, with which to keep up the system of railroads traversing the great plains to the Pacific Ocean, as the old west formerly looked to Pennsylvania. In Indiana we find the last great belt of timber, suitable for manufacturing purposes, and after crossing her borders, thence to the Pacific ocean, no coal has yet been found that can successfully be used in the manufacture of iron.

Professor A. H. WORTHEN remarked, we have found the same difficulty in Illinois in reconciling our section of the Coal measures strata with those of Kentucky, that has been alluded to by Professor Cox, in the paper just read, as occurring with him in Indiana. On attempting to synchronize our coals with those of Dr. Owen's published section, I very soon found that it could not be done, and that if the Kentucky section was correct, no parallelism could be drawn between them. From further examinations I became satisfied that the Kentucky section was erroneous, and that by giving distinct names to different outcrops of the same sandstone, in its outcrops at different localities, they had duplicated the number of their workable coals, and also the thickness of the coal strata. This was shown in the first chapter of the third volume of the Report on the Geological Survey of Illinois, published in 1866, where, by placing these two sandstones on the same geological level, it was found that the strata underlying them formed sections, as nearly identical as they could be made anywhere in the coal series, at points twenty miles asunder. By reducing their section in this way, we find there a general correspondence between the strata in Illinois and Kentucky, as nearly complete, perhaps, as could be expected in opposite portions of the same coal-field. The coal-seams of Western and Northern Illinois are usually continuous over large areas, as much so indeed as the limestones, shales, and sandstones, with which they are associated.

Professor SWALLOW remarked that he had greatly enjoyed the examina-

tion of the Indiana "Block Coals." He believed they would become sources of vast wealth. But his friend Prof. Cox must not be sure other states would not furnish the same quality of coal.

He had for many years burned a coal which is so much like Indiana Block Coal, that Prof. Cox himself could not distinguish them.

But no opportunity had been offered for publishing the results of the Missouri Survey.

NUMERIC RELATIONS OF THE VERTEBRATE SYSTEM.—BY DR. T. C. HILGARD.

THERE are five (not four only) complete neural rib arches to the cranium of all vertebrate animals, to wit: (1) The condylar or sensitive belt with the condyle plates for side ribs and the lower arch of the *transversely bipartite* occiput for its vault piece; (2) the petrosal or *acoustic*, containing the auditory nerves in its side beams (easily detected by removing the ear drum of Felines, etc.), and overarched by the anterior belt of the occipital squama; (3) the parietal belt originally containing the true gustative nerve of fixed tastes (sour, sweet, salt and bitter, the glosso-pharyngeal), in an incision; from which it is, however, soon crowded out by the internal carotid artery and the overlapping "acoustic rib blade." The next (4) is the optic or frontal, visibly succeeded, in fishes, by (5) the ethmoidal or olfactory vertebra. The rest of the cranium is formed by its "extremities" or prehensile appendages.

The same numeric law which pervades the entire vegetable kingdom reoccurs in the human fabric in a very marked manner.

The number of "radiating elements" in a coil or whorl, or of whorls in a cycle, or in cycles generally speaking, as in pine cones and flower buds, etc., are the following:

1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, etc., progressing by the summation of the last two numbers.

The bands or parallel coils of flowers or scales in pine cones, sunflower discs, etc., embody these numbers successively, as they grow steeper and steeper, alternately on the right and left. The vertical bands, or columns, give the number of parts of the cycles involved.

The explanation heretofore given by me is this, that one element generates the other.

The elements are radial; they are bilateral rays, with a rift, so to speak, on the opposite side. It is there, where, in a like manner

as the seed-leaves of flowering plants produce prolific "ovules," new radial organs are developed from the preceding ones — laterally at alternate heights and toward the wider spaces.

This process, referred to the radial organs of plants in an early stage, will yield:

1. The *numbers* of parts in question, successively.

2. The peculiar law of *interpolations* or of "divergence," viz.: by a number of interstices represented by the second preceding one of each cyclar number.

3. It will *conclude* the cycles, if it be supposed that the activity of each junior member depends on that of its progenital one; as in all cases of simple branch developments.

These numbers occur in like manner in the human frame, as follows:

Inclusive of the terminal (ossified or gristly) coccygeal element, we have exactly thirty-four spinal vertebræ.

Classifying nerves by their *work*, or "function," we find —

3 pairs of cervical nerves (neck).

5 pairs of brachial nerves (arms).

8 pairs of pedal nerves, composed of 3 crural (lumbar) and 5 ischiadic (sacral) ones.

13 pairs of nerves to the rump.

5 specific ones of the cranium.

—

34 in all; whereas the number of the spinal vertebræ, which inclose the spinal cord is exactly 21.

There are five pairs of "extremities," organized after a common plan: (1) the lower, (2) the upper, (3) the temporal, (bearing the lower jaw for a "member,") (4) the palate-facial, with the upper jaw for its "member," (5) the opercular or hyo-tympanic one, forming the gill-lid in fishes or the tympanic ossicles in man; and the digital extremity of which is gradually converted into the (hand-like) crimped (external and internal) cartilages of the ear.

The five pair of hæmal arches of the cranium, *i. e.*, the gill arches of fishes, are gradually transformed into the gristles of the gullet, etc.

The main variation consists in the varying, but "cyclar" number of "rays," — fingers, etc.; the varying cyclar number of their joints (1, 2, 5, 8, 13 respectively, in a dolphin, with five carpals, instead of eight, as in man) and the varying cyclar number of

"loose" ossicles, such as *carpals*, *tarsals*, *teeth*, etc. The number of spinal vertebræ, is also variable, but not that of the cranial ones.

The vertebral blocks, as well as the ribs, are the product of the primitive axial series of (intervertebral) discs, which, when completely arrayed, each bear five branches, viz.: two pair of hæmal arches, two pair of neural arches, and a fascicle of parallel cleets, so to speak, which being *cemented* together, both in the front and rear, by the superficial ossification of the discs at either end are fused into the block pieces, as found, *e. g.*, in the young hog; the cementing slab covering the big neural rib head likewise, and not only the pentagonal prismatic block. The first disciform ossification we find in the corals, forming cribrose ethmoidal discs, such as the closely set "sigillate impressions" of the Astraea, and afterwards left behind as the coccyx, *e. g.*, of Cyathophyllum.

On the Earthquake of October, 1870. — By Col. Charles Whittlesey.

The writer confined his attention to what he pronounced the only remarkable feature of the earthquake, which was its occurrence at far distant points almost at the same moment of absolute time. Out of thirty odd observations made at as many different points in the United States, four were known to be accurate to within fifteen seconds, so that the total error could not exceed thirty seconds. Making the necessary allowance for difference of longitude, it occurred at Cleveland, Ohio, at 10 hours 43 minutes 30 seconds; at Albany, New York, 10 hours 43 minutes 9 seconds; at Boston, Mass., at 10 hours 43 minutes and 25 seconds; and at Bangor, Maine, at 10 hours 43 minutes and 19 seconds. The difference, therefore, was only in seconds. The ordinary rate of progression of earthquakes is from twenty to thirty miles an hour; while this one, if it progressed at all, must have moved at the rate of a thousand miles an hour. The paper was intended to raise the question: What kind of an earthquake was it?

Professor McChesney asked whether the author of the paper had given any attention to the subject in connection with the repulsion theories of Dr. Winslow of Boston.

Colonel Whittlesey stated that he had made very little progress toward a theoretical explanation of the phenomenon; he believed, however, that

the earthquake in the case in question was not progressive at all, but that it was produced by some force within the earth, acting outward.

Professor ANDREWS stated that he had observed the earthquake at Columbus, Ohio, and was struck by the fact that the motion, instead of being a sudden shock or jar, as is commonly the case, was like the gentle undulation of a boat in the water. He thought if the earthquake had been the result of a sudden explosion directly beneath, there would have been a sudden jar instead of this undulatory motion. It might possibly be accounted for by the fact that there is a blanket of drift material from eighty to one hundred feet in thickness underlying Columbus, which might serve to break the force of the concussion.

Professor WINCHELL thought the suggestion of Professor Andrews would be applicable to the phenomena in connection with this earthquake, if those phenomena had not had an existence over so wide an area. It seemed incredible that anything like an earthquake wave should have been transmitted from any superficial location along the earth's surface with anything like the rapidity that was indicated.

There must have been a deep-seated force exerted, the results of which reached the surface at remote points nearly at the same time. It would seem to indicate that the seat of earthquake activities is at some point within the earth, far removed from its surface. He thought evidence might possibly be found in this phenomenon, tending to corroborate the theory of some geologists in reference to the fluid condition of the earth's interior, and the comparative thinness of the solid crust upon which the mountains have been reared.

## ON THE EXTINCT TORTOISES OF THE CRETACEOUS OF NEW JERSEY. BY PROFESSOR E. D. COPE.

HIS object was to explain two cases of "generalized groups," such as are not common, comparatively speaking, and are of much importance in the history of life. Generalized or synthetic groups of naturalists were explained to be those which combined the characters of others. They were generally found in earlier geologic time, while the more widely differing groups occurred later in time. The cases were as follows. It was explained that the existing division of the marine turtles (*Cheloniidæ*) possess sternal bones united by but few sutures, or with wide intervals; straight humerus and femur, and flat limbs, with truncate finger-bones incapable of flexion. It was shown that the existing snapping tortoises possess a narrow cross-shaped sternum with the bones everywhere united to each other, the femur and humerus curved, and the toes with hinge-jointed phalanges capable of much flexion. It was then pointed out that in the New Jersey Green

sand a type of turtles is found, embracing several genera and species, in which the sternum has the elements generally united by sutures, except two central fontanelles, being thus intermediate between that of the *Cheloniidæ* and that of the Chelydras (snappers); that the femur and humerus are curved, as in the snappers, but the limbs are oar-like bodies with truncate phalanges, as in the sea-turtles. This family he called the *Propleuridæ*.

The second case was presented by tortoises of a character like those now inhabiting fresh waters. The *Emydidæ*, or common river tortoises of the northern hemisphere, were shown to possess ten horny shields on the plastron (or lower shell), had a pelvis freely suspended from the carapace (upper shell), and a series of cervical vertebræ which can be curved in an S, and the head thereby drawn into the shell in a vertical plane. The southern hemisphere division of the *Pleurodira*, possesses eleven scuta of the plastron, a pelvis, of which the pubis and ischium unite by sutures with two corresponding elevations of the plastron, and a neck which can not be sigmoidally flexed, but is thrown round to one side, like that of a bird, when it is necessary to conceal the head.

It was shown that in the Cretaceous of New Jersey there existed a family (the *Adocidæ*) which combined the features of these groups. It had eleven scuta of the plastron (the extra one being large and anterior), but the lower bones of the pelvis were not coössified with the plastron, though the latter rose in two corresponding elevations. The latter were evidently rudiments of the articulating knobs of the *Pleurodira*.

Professor Cope stated, moreover, that the *Adocidæ* possessed a row of scuta across "the bridge," within the marginal row, such as existed in modern times in the sea-turtle, and in the Mississippi snapper, thus adding very much to the generalized character of the *Adocidæ*.

Turning to the tortoises of the Eocene beds of Fort Bridger, Wyoming, he showed that these were true *Emydidæ*, but that many of them retained the inter-marginal series of scutes, abovementioned (*Baptemys*, etc.), so far resembling the *Adocidæ*. Among existing typical *Emydidæ*, but one genus presents the character, viz., the *Dermatemys* of Mexico.

The value of these generalized groups was pointed out as consisting in their correction of our views derived from the great

constancy of specific characters. These, he showed, remained unaltered throughout great extents of time and space, and other slight structural characters endured through many geologic ages. Hence the value of cases where the association of characters is evidently in a transitional condition.

THE EMBRYOLOGY OF CHRYSOPA, AND ITS BEARINGS ON THE CLASSIFICATION OF THE NEUROPTERA.—BY A. S. PACKARD, JR., M.D.

IN a paper presented at the Burlington meeting of the Association in 1867, I gave a brief sketch of the embryology of Diplax, especially in the later stages. Those observations, with the far more carefully elaborated studies of Brandt * on Calopteryx, another member of the family Libellulidæ, have made us acquainted with the embryology of the type of one important division of Neuroptera, and now I have to offer a partial history of Chrysopa, the representative of another important division of the group. I did not observe the formation of the blastoderm, but the blastodermic skin ("amnion") of Chrysopa, is of the same structure as in Calopteryx. At the posterior end of the egg the round nucleated cells are crowded together in the same way as in Calopteryx. The primitive band is of the same general form, and floats in the yolk as in Calopteryx, but more as in Aspidiotus, though it rests more on the outside of the yolk than in those genera, and the end of the abdomen rests on the outside of the yolk, rather than rolled in within the yolk; but that the germ is an endoblast (so far as that condition has any special significance) is shown by the fact that the ventral side of the primitive band points inwards towards the centre of the yolk, as in the Libellulidæ, the Hemiptera, and some Coleoptera (Telephorus and Donacia) in contradistinction to the Phryganeidæ and the Poduræ (Isotoma) in which the germ or primitive band floats entirely on the outside of the yolk. After the procephalic lobes and rudiments of the appendages of the head and thorax have begun to develop, a second moult (visceral layer) of the blastoderm is made, which envelops the head and under side of the body much as in the Libellulidæ and Hemiptera. At this time the embryo is much like that of the last named insects. The germ does not revolve in the egg, as

* Beiträge zur Entwicklungsgeschichte der Libelluliden und Hemipteren. St. Petersburg. 1869.

in the Libellulidæ, but the head remains throughout embryonic life next the micropyle. At the next stage observed, the appendages of the limbs had appeared, the embryo being situated on the outside of the yolk, the end of the abdomen curved around on the opposite side of the yolk. At this time the inner or "visceral layer," forming a second moult of the blastoderm, envelops the germ, much as in the Libellulidæ, and Hemiptera, and Coleoptera (Donacia). It is evident that this *faltenblatt* of Weismann (or visceral layer of Brandt) is shed at a later stage than the "amnion" proper. This stage corresponds with that of Calopteryx figured by Brandt (Pl. 1. fig. 11). At this time the germ of Diplax and Calopteryx (Libellulidæ) floats within the yolk, but this difference I would regard as having no special importance, as in the Hemiptera the germ at the same stage of development rests on the outside of the yolk in Corixa, while in the Pediculina, according to Melnikow's researches, the germ floats within the yolk, and we shall see farther on that in the Curculionidæ (Attelabus) the germ rests on the outside of the yolk (ectoblast), while that of Telephorus is a decided endoblast, *i. e.*, floats in the interior of the yolk. After this period, the embryo of Chrysopa exactly corresponds to that of all the Libellulidæ whose development is known (Agrion, Calopteryx, Perithemis, and Diplax.)

The embryogeny of Chrysopa is identical, then, with that of the Libellulidæ. What becomes, therefore, of the distinction between the "Pseudoneuroptera" and "true" Neuroptera, insisted on by some of the leading entomologists, since Erichson's day? Never believing that the differences were great enough to separate the Linnæan Neuroptera into two independent orders or suborders (whichever we may choose to call them), I now ask if embryology does not give independent testimony as to the close alliance at least of the Libellulidæ and Hemerobidæ, even if we go no farther?

The only Coleoptera with whose development we are acquainted is Donacia, worked out more carefully by Melnikow than any one else. During this summer I have studied *Telephorus fraxini* and *Attelabus rhois* in nearly all their embryonic stages. They are developed in the same manner as in Donacia. There is a parietal ("amnion") and a visceral membrane in Attelabus; (it was not observed in Telephorus, though it doubtless exists), as in Donacia. In Attelabus, however, the primitive band rests on the outside of the yolk, while in Telephorus it floats in the yolk, and forms a

sigmoid band, extending back to the posterior pole of the egg. But after the rudiments of the limbs appear, the embryology of both genera accords with that of Donacia. I have found that the embryology of *Gastrophysa cœruleipennis* in its later stages also agrees with that of Donacia, (both being Chrysomelids.) A study of the development of *Nematus ventricosus*, shows us that its embryology accords with that of *Apis mellifica*. The formation of the blastoderm is as described by Bütschli in Apis,* and quite unlike that of the Formicidæ as studied by Ganin. It also agrees with that of the Diptera in most particulars.

There is indeed a remarkable uniformity in the mode of development of the Hexapoda, as much so perhaps as in the Crustacea (Malacostraca), and it is difficult to determine what embryological characters may be set down as distinguishing even the different suborders. These characters, whatever they may be, do not probably reside in the embryonal membranes, or in the relation of the primitive band to the yolk. Perhaps they will be found in the form of the advanced embryos. For example, we now know that the embryos of the Isopod Crustacea only differ from those of the Amphipods while in the egg by having the end of the abdomen bent over the back, while in the latter (Amphipods) it is curved beneath the body, as pointed out by Fritz Müller. The spiders and scorpions also pass through a similar course of development, and the Mites (Acarina) are developed in a manner either identical with the spiders in some genera, or more like the Hexapods in others. We know almost nothing of the embryology of the Myriapods, but Newport's observations on Julus indicate that it is developed in an entirely different mode from the Hexapoda or Arachnida, a remarkable feature being the persistence of the larva in its inner (?) embryonal membrane (*faltenblatt* of Weissmann) for many days after it is hatched.

There are, however, two modes of development in the Hexapoda, depending on the position of the primitive band in relation to the yolk. The Hymenoptera, Diptera, and certain Coleoptera (Curculionidæ), and the Phryganeidæ and Poduræ (Isotoma) are *ectoblasts*, † while the Hemiptera and certain Neuroptera (Libellulidæ

*Dr. O. Bütschli. Zur Entwicklungsgeschichte der Biene; Siebold and Kolliker's Zeitschrift, 1870. p. 519.

† I omit any reference to the Lepidoptera, which Dr. Dohrn regards as endoblasts but which I am inclined from some eggs (probably of an Arctian) I have studied to regard as developing like the Hymenoptera and Diptera.

and Hemerobidæ) are *endoblasts*, to use Dr. Dohrn's terms. On inquiring how far these two modes correspond to the degree of development of the insect on leaving the egg, and the degree of metamorphosis of the insect before becoming adult, it seems that the endoblasts occur in those ametabolous insects (Hemiptera and Neuroptera) with flattened, leptiform larvæ, and also in those Coleoptera with similar larvæ, as distinguished from the weevils, which have eruciform larvæ, *i. e.*, resembling the maggots of Diptera and Hymenoptera. The two modes of development, then, do not fully accord with the two different degrees of metamorphosis of insects, but more probably depends simply on the form of the larva when hatched. Now there are two forms of insectean larvæ which are pretty constant. One we may call *leptiform*, from its general resemblance to the larvæ of the mites (Leptus). The larvæ of all the Neuroptera, except those of the Phryganeidæ and Panorpidæ (which are cylindrical and resemble caterpillars), are more or less leptiform, *i. e.*, have a flattened or oval body, with large thoracic legs. Such are the larvæ of the Orthoptera and Hemiptera, and the Coleoptera (except the Curculionidæ; possibly the Cerambycidæ and Buprestidæ, which approach the maggot-like form of the larvæ of weevils). On the other hand, taking the caterpillar or bee larva with their cylindrical fleshy bodies, in most respects typical of the larval forms of the Hymenoptera, Lepidoptera and Diptera, as the type of the *eruciform* larva, we find that those insects with such larvæ are ectoblasts. (The Poduræ which, as in Isotoma, are ectoblasts, and are certainly leptiform when hatched, form an apparent exception.) Thus the two modes of development (ectoblastic or endoblastic) perhaps simply depend on the form of the insect when hatched, and its mode of life.

The leptiform larvæ of insects may be compared with the nauplius form of Crustacea, and in a much less degree the eruciform to the zoea form. The three higher suborders of insects may be compared to the Malacostraca with their zoeæ form larvæ, and the four lower suborders (Coleoptera, Hemiptera, Orthoptera and Neuroptera) with the Entomostraca,* in which certain forms, as in some Phyllopods, and Limulus, and the Trilobites, are hatched in a subzoea condition (corresponding to the eruciform larvæ among the Neuroptera and Coleoptera). The larvæ of the earliest insects

* The terms Malacostraca and Entomostraca are used for convenience, not that they are entirely natural divisions.

were probably leptiform, and the eruciform condition is consequently an acquired one, as suggested by Fritz Müller.* His suggestion, followed up by Brauer, that the insects have descended from some zoea does not seem of much value, as the leptiform larva more exactly parallels the nauplius of the lowest Entomostraca (Copepoda). We have already suggested that the Insects and Crustacea probably arose by two distinct lines of development from the worms, rather than that the Nauplius gave rise to the Insects, as Müller has suggested; an important reason for this view being that the three pairs of appendages of the Nauplius do not homologize with the distinct cephalic and three thoracic appendages of the Leptus.

## The Organic Identity of the Albumen and Endopleura of all the Phanerogamæ.—By T. C. Hilgard, M. D.

All seeds of the flowering plants (the net-leaved, blade-leaved and the pine tribes) are collectively described as consisting of a *germ* or "embryo," enclosed within *two separate seed-coats.*

A great many seeds, like those of the mustard, nasturtium, buck-eye, bladder-nut, the ailanthus, sumach, china-tree, orange, camellia; the gum-pod ("gumbo"), hibiscus, the cocoa-bean, almond, pea and rose-tribes, the brazil-nut, walnut, chestnut; the cockle-bur, sun-flower and melon all conform to this description, and the natural tribes to which they belong form a connected region of the flowering plants generally speaking.

It is likewise understood that a great many seeds have their germ proper imbedded in a bulky, nutritive lump called the "*albumen*"; which thus forms the main bulk of the seed, *e. g.* of the ivory-nut, the date-kernel, the cocoa-nut, the pepper, paw-paw and nutmeg, and all the grains no less than the well known coffee-bean. In water, the latter will swell and protrude its stubble-like embryo out of one end of its horny, enveloping mass, or "*albumen.*"

It has, however, hitherto remained an unnoticed fact that all seeds which have *two* so-called seed-coats, are all alike *destitute of*

* "It is my opinion that the 'incomplete metamorphosis' of the Orthoptera is the primitive one, *inherited* from the original parents of all insects, and the 'complete metamorphosis' of the Coleoptera, Diptera, etc., a subsequently acquired one."—*Für Darwin.* Eng. Trans. p. 121.

*an* "*albumen*;" and that all seeds *provided* with an albumen, have only one *solitary seed-coat, aside from the albumen itself.* *

In many other seeds, as in those of the Osage orange (Maclura) and several Cactaceæ, etc., the albumen is thinned out, in some places, into a so-called "endopleura" or interior seed-coat, while in other parts of the seed the sheet of this self-same "internal seed-coat" thickens up into a bulky albumen, conformably to the configuration of the germ it encloses and of the *testa* which contains both.

An inspection of the *immature seed* of all the so-called *ex*-albuminous forms, *i. e.* those which, like the pea-nut, peach, and almond, are destitute of an albumen, discloses the fact, that in this juvenile condition, all these seeds, have, like all the rest (viz. the "albuminous seeds") a large *succulent albumen-zone*, wherein the germ ("embryo sac" etc.) is developed, at the expense of the former. During the process of ripening, in all the *nutty*, or "*ex*-albuminous" seeds, the primitive albumen becomes gradually *exhausted*, leaving its entire cell-tissue compressed and empty behind, as the delicate endopleura or internal seed-coat. In all the other seeds, on the contrary, this succulent albumen-zone remains the storehouse for the germinating seed to draw its substance from. In the honey-locust and the allied coffee-nut tree (Gymnocladus) in germination, the flinty albumen dissolves into a sort of gum, like gum arabic.

In point of fact, the "endopleura" and the "albumen" are one *identical organ*.

This evident identity of the original albumen and subsequent second seed-coat, settles at once the old and perplexed question about the erroneously supposed "*gymnospermism*," whether of Labiatæ, Coniferæ and their allies, the Taxineæ, Gnetaceæ, Casuarinæ and Cycadeæ.

Since we now know, what *parts* all seeds *consist of*, these tribes are by no means to be considered as "abnormally" or even "monstrously" organized (as a prevalent theory still holds) but that *e. g.* all the *edible pine-nuts* contain, each, a *complete seed*; which loosely adheres to the capsule (like the mature cocoa-nut

* The testa, or exterior seed-coat, frequently exhibits a diversified structure of external and internal surfaces. In the seed of the magnolia, that of the grape, etc, the exterior surface of the otherwise bony seed-coat, which encloses the albumen, is fleshy; as is the entire testa of the blue cohosh (Caulophyllum.)

kernel) and is encased within a one-seeded pistil, as is the case *e. g.* with all grasses, grains and the knot-weeds; their true ovules being mostly sessile (as in the entire orders of Polygonaceæ and Nyctaginaceæ, with only few exceptions) and considerably coherent with the true pistil (or stigmatiferous "utricle"). In the above-mentioned coniferous tribes, these one-seeded pistils are provided with a pervious, "open" stigma; a case correspondingly represented in the duck-weeds (Lemnaceæ) which however have their seeds borne upon a *funiculus*.

The seed itself, of Coniferæ, is a complete one, consisting (1) of a germ; (2) an (oily) albumen and (3) one thin, brown, membranaceous seed-coat (the *testa*), readily separating from the utricle or nut-shell which surrounds it, as in the well-known cases of the pine-nuts of California, Italy and that of Switzerland (*Pinus lembra*).

Thus, it is clear that the pine-*scales* are only a woody cup or *cob*, of indurated "saucers" or involucres (as with acorns) that arise in the axils of delicate and sometimes colored bracts. Similar involucral cups we find in the harsh cones of the alder, and in the sterile aments of the wild hemp tribe.

The wing-like appendages of the pine-nuts represent so many *paleæ* or *floral chaff* (like that of grains and bulrushes, etc).

In the remarkable case of Welwitschia, the "kettle-drum pine" of western tropical Africa, no such indurated scales, but only the purpureous bracts, as are those of flowering larch-trees, are developed. The true *perianth*—judging by Dr. J. D. Hooker's plate viii—being here a delicate, foliaceous two-winged one, epigynously concrete with the nut, as is the chaff of pines and two-seeded capsules of Araucariæ. Nevertheless, the same identical organ is erroneously styled "a pericarp" on the preceding plates, by a *lapsus calami* of the same author, on the uncritical bias of *so-called* "gymnospermism."* The so-called gymnosperms have *closed pistils!*

It is thus clear, that there is *no* "*break*" in the vegetable kingdom: all forms uniting into a complete, connected and harmonious

* The untenable theory, here referred to, considers the pine-*scale* as a "pistil;" destitute, however, of any of the *distinctive attributes* of a pistil, being without a suture, without a stigma, and without any fructification through its instrumentality.

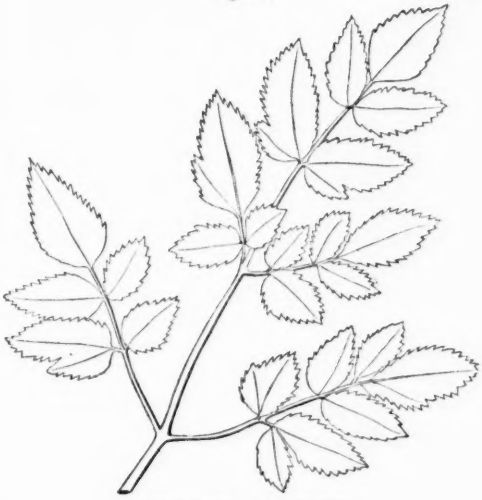
The true (one-seeded, *pluri-ovulate*) pistil, or "utricle," was wrongly regarded as an (abnormally "*naked*") "ovule"; with an *abnormally rostrate* "exostome," viz: the (open) stigma! Next follows (after this *pseudo* "testa") the true seed-coat under the

system of mutual typical affinities or correlations, to be discussed in detail in a subsequent paper.

## Inequilateral Leaves.—By Professor W. J. Beal.

The leaves of most plants, such as those of the white oak, sugar maple, and tulip tree are equilateral, *i. e.*, the right and left sides are of the same size and match each other, as the two sides of the

Fig. 100.



Compound leaf. After Spencer.

nose and chin, or the right hand and foot match the left. Some simple leaves and many leaflets of compound leaves show a marked

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denomination of an "endopleura",—and an "*albumen*" *besides*, which contains the embryo.

The true solitary seed-coat adhering to the pistil, the shrunken albumen will often be found lying loose inside.

The contended fruit of the well-known yew-tree contains (1) an embryo, imbedded within (2) an albumen, which is surrounded (3) by a tawny seed-coat. The latter loosely adheres to a thickish *capsule*, which is itself *covered by a thick, calycine layer*!—in the exact likeness of an acorn, a hazelnut, or the nut of the sweet gale (Myrica; the wax-myrtle or bayberry) which indeed seems to reproduce the true (*epigynous*) structure of the former on a reduced scale; as the (Composite) *Polymnia Uvedalia* or "nutted leaf-cup."

The cup of the yew-tree thus remains to be properly interpreted as a fleshy cup partly of dry scales, like those of the acorn and wax-myrtle on the one, and the succulent Euphorbia-involucres on the other hand.

want of symmetry in their lobes. The *Begonia* is often cited as an example. The hickory, bean and poison ivy, may illustrate the same thing in compound leaves. In figure 100, "The homologous parts a, b, c, d, while they are unlike one another, are, in their main proportions, severally like the parts with which they are paired. And here let us not overlook a characteristic which is less conspicuous but not less significant. Each of the lateral wings has winglets that are larger on the one side than on the other; and in each case the two sides are dissimilarly conditioned. Even in the several components of each wing may be traced alike divergence from symmetry, along with a like inequality in the relations to the rest; the proximal half of each leaflet is habitually larger than the distal half." (Herbert Spencer, Principles of Biology, fig. 65, p. 31.)

A. P. De Candolle says, "This inequality generally exists only in alternate leaves, and I cannot find in my memoranda any example of an inequilateral opposite leaf. This fact tends to prove, that this inequality ought to be referred to the position of the leaf upon the plant favoring the development of one of its sides more than the other; and in this case, it is always the lower one which is developed most. This law is still more evident in the leaflets of pinnate leaves . . . . the side most developed is always the lower, the upper being narrower and less prolonged. The same observation may be made upon the stipules, which are very frequently irregular. In opposite leaves, there has been presented a curious example of inequality in *Ruellia anisophylla;* — one of two opposite leaves is very small and narrow, and, as it were, abortive in comparison with the other; but symmetry is also met with in this irregularity, for on comparing the successive pairs, the small leaf is found alternately on both sides. Stipules [sometimes] present analogous phenomena."

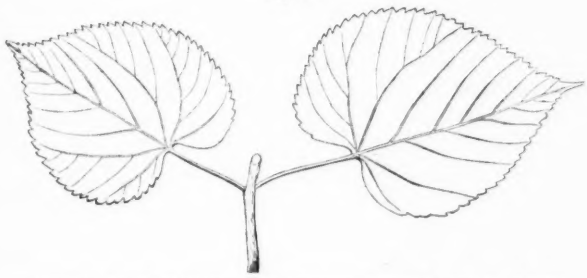
Dr. Wilder has shown that "Elm leaves have the *inner* or *upper* side much larger," thus upsetting De Candolle's theory that the inequality is due to the position of the leaf upon the stem. Various other reasons have been assigned for this inequality, all of which seem to fail when applied to numerous examples in their various stages of development.

Schleiden believes that this want of symmetry is due to unequal pressure in the bud. Spencer seems in doubt about the true cause, for he says, "How far such differences are due to the positions of the parts in the bud; how far the respective spaces

available for the parts when unfolded affect them; and how far the parts are rendered unlike by unlikenesses in their relations to light, it is difficult to say. Probably, these several factors operate in all varieties of proportion." He attributes the want of symmetry in the leaves of the Lime tree or basswood to the shading of the smallest lobes. That this cannot be the case is proven by an examination of the conduplicate leaves of the basswood and elm while in the bud. When less than half an inch in length, the lobes are plainly unequal. When much less than a fourth of an inch long they are nearly or quite equal lobed. Since noticing these facts, the writer was pleased to find the same views recorded by Dr. Wilder.

On the basswood, the leaves are alternate and two ranked, having the upper lobe fullest. This is the case even where the

Fig. 101.

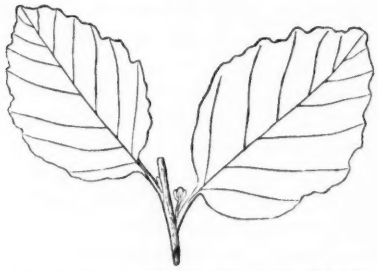


Alternate two ranked leaves of *Tilia Americana*, Basswood, fullest at the base on the inner side.

full lobe is shaded or where the whole leaf is well exposed to the light. Spencer gives an illustration showing the arrangemennt of basswood leaves, exposing nearly all their upper surface to the light. If he should turn a young branch over, of this or almost any other plant, he might be surprised to see how soon the leaves would turn back again, and how nicely they would adapt themselves to each other, economizing all the available space. The leaves of red elm and the American elm are sessile, broad at the base, two ranked with the upper lobe fullest. The same is true of the blue beech, *Carpinus Americana*, though the lobes are often equilateral. *Celtis occidentalis* has two ranked leaves with petioles half an inch long. The upper lobes of the leaves are very full when compared with those of the elm. Begonia leaves are two

ranked with the upper lobe fullest, no matter whether they are nearly sessile or on petioles a foot in length. The witch hazel has two ranked leaves with a broad base on short petioles and the lower lobe much the fuller. The common beech, hazel, mulberry, and grape have two ranked, equal lobed leaves.

Fig. 102.

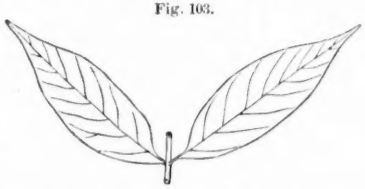


Alternate two ranked leaves of *Hamamelis Virginica*, Witch Hazel, fullest at the base on the lower side.

It is a very common thing to see a want of symmetry in the lobes of leaflets of compound leaves. The reader will remember that De Candolle says, "The upper edge of such is always smallest."

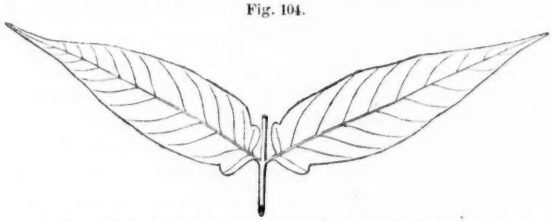
Of this character, we find the black ash, the hop-tree (*Ptelea*), bean, hickory, elder, bladder-nut (*Staphylea*), strawberry, poison ivy, fragrant sumach, and Jack in the pulpit (*Arisæma*). The ultimate divisions of the decompound leaves of Hercules club are fullest on the lower side, while the leaves of the Kentucky coffee-tree reverse the above example. The leaflets of Ailanthus are broad at the base, and raised on very short

Fig. 103.



Two leaflets of *Fraxinus sambucifolia*, Black Ash, fullest on the outer lobes.

Fig. 104.



Two leaflets of *Ailanthus glandulosus*, fullest on the inner side.

pedicels. The upper edge of their leaflets is much the fuller. Leaflets of the Southern prickly ash are fuller on the upper side,

while those of the Northern prickly ash, of the same genus, are usually fuller on the lower side. *Rhus toxicodendron* has the lower edge of the side leaflets fuller; *Rhus copalina* has the upper edge fuller. For some time, I thought as De Candolle wrote (though I had not then read his book on the subject), that the unequal lobed leaves were all alternate; and further, I thought they were all two ranked along the stem, and thus set off against each other, as leaflets in a compound leaf. I was not much surprised, however, though much interested to find that the opposite leaves of *Cornus Florida* were fuller on the lower edge, as they were all turned horizontally on the side branches. On the 4th of July, the two terminal leaves were about half grown and generally equal lobed at the base, though not always so. I find the opposite leaves of several of our Euphorbias, as noticed in Gray's manual, are fuller at the lower edge as they are turned down horizontally. In a somewhat similar manner are the two parts of the involucre of *Carpinus Americana*. These stand with the fuller edge away from the axis. The two edges of each are unequally serrate, more serrate on one edge than on the other, so the involucral leaves match as well as the corresponding fingers on our two hands. In the greenhouse of the Michigan State Agricultural College, is a plant unknown to me, presented by Dr. Gray. The leaves are on petioles three-fourths of an inch in length; they are probably three ranked (certainly not two ranked). As the leaves droop, the upper lobe is much fullest and the midrib considerably curved as in *Begonia*.

Fig. 105.

Two opposite leaves of *Euphorbia maculata*, fullest on the lower side.

Fig. 106.

Involucre of *Carpinus Americana*, Blue Beech, the upper or inner lobe narrower which grew next the axis.

So we have unequal lobed leaves on stems where they are two, three or four ranked. The common sheep sorrel often has one lobe longer and larger at the base, but I am unable to find any rule with regard to this fact.

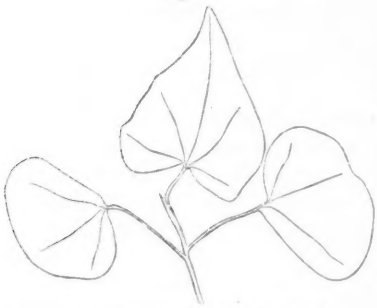
The four o'clock of our gardens *Mirabilis* has opposite leaves, and when of proper size, terminates each axis with a flower. The axillary bud on each side develops into a branch terminating

in the same manner by a flower. Thus we have four leaves in two pairs closely sitting about a flower. As thus arranged spreading each way they are all fuller at the base on the side next the flower, where there is least light and least room. This is contrary to what we should expect according to De Candolle and Spencer. An examination of the plant for a moment will make it clear.

Every botanist is familiar with the unsymmetrical petals on the sides of the pea flower, violet, lobes of mint blossom, and those of other plants.

The strangest thing under *want of symmetry* that I have seen in plants, is found in the cotyledons of our cultivated buckwheat. While in the seed, they are pressed together, and rolled up from one edge. When the cotyledons have acquired their full growth, they have petioles about half an inch long; *each* cotyledon is fullest on its *left* side, so they would not match each other without turning one of them over. Perhaps this is a puzzle analogous to homologizing the hand and foot on the same side of the body. All our theories so far read or imagined, such as influence of heat, light, gravitation, number of ranks on the stem, length of petiole, pressure, natural selection, do not satisfactorily explain all these peculiarities.

Fig. 107.



Cotyledons of *Fagopyrum esculentum*, Buckwheat, each fullest on right lobe.

So far, we agree with Dr. Wilder, "That such peculiarities are true and original characteristics of the plants, and that they are produced by the so-called vital force acting in a definite way."

## On the Oil Wells of Terre Haute, Indiana.—By Dr. T. Sterry Hunt.

In previous publications, I have endeavored to show that the source of the petroleum in southwestern Ontario, and probably in some other localities, is to be sought in the oleiferous limestones of the Corniferous and Niagara formations, both of which abound

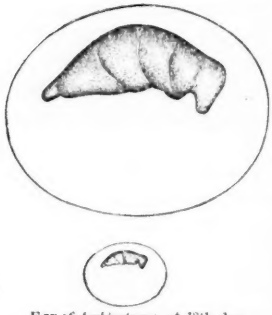
in indigenous petroleum. I have, moreover, expressed the opinion that the overlying sandstones of Pennsylvania are also truly oleiferous. In a paper read to this Association last year, I showed that the Niagara limestone at Chicago holds imprisoned in its pores an enormous quantity of oil, and remarked that the reservoirs which supply the wells in other districts are fissures along anticlinals, which fissures, though sometimes occurring in strata above the oil-bearing horizon, in Ontario frequently occur in the Corniferous limestone itself. Hence the view held by some that the source of the oil in that region is to be sought in the overlying strata, is negatived. In Ontario, there intervenes between the Corniferous and Niagara formations the great saliferous series known as the Onondaga or Salina formation. This, however, is wanting to the westward, where the first two formations come together, and, according to Prof. Cox, where exposed at North Vernon, Indiana, are both oleiferous.

A well lately sunk at Terre Haute, Indiana, in search of fresh water has shown the existence of a productive source of oil in that region. It was carried nineteen hundred feet, and yields about two barrels of oil daily. A second well, a quarter of a mile east of north from the first, now gives a supply of twenty-five barrels of oil daily. After passing through one hundred and fifty feet of superficial sand and gravel, the boring was carried to a depth of sixteen hundred and twenty-five feet, where oil was struck. According to Prof. Cox, the strata passed through are as follows: Coal measures, seven hundred feet; Carboniferous limestones with underlying sandstones and shales, seven hundred feet; black pyroschists regarded as the equivalent of the Genessee slates, fifty feet. Beneath, at a depth of twenty-five feet in the underlying Corniferous limestone, the oil-vein was met with. The oil in the first well was found at the same horizon. A third well about a mile to the westward, was carried to two thousand feet, but only traces of oil were found. This locality, on the Wabash river is, according to Prof. Cox, on the line of a gentle anticlinal or uplift, which is traced a long distance to the west of south. This relation of productive oil-wells to such anticlinals was pointed out by Prof. Andrews and by myself in 1861.

THE DEVELOPMENT OF AMBLYSTOMA LURIDA SAGER.—BY DR. P. R. HOY.

THIS, the largest of the North American salamanders, affords superior facilities for studying the habits and embryonic changes from the egg to the perfected reptile. The adult female of this species is from eleven to twelve inches in length. The male is rather less. They excavate holes in the ground in which they conceal their bodies, the head only being visible. Thus they lie in wait for stray slugs and insects on which they subsist. Late in th fall they stray about seeking a hiding place in which to hibernate, at which time they frequently find their way into cellars to the great consternation of the household.

Fig. 108.



Egg of *Amblystoma*, at 13th day Lower figure of natural size.

Early in the spring they repair to neighboring ponds, in which to deposit their eggs, which they place in packets of from twenty to fifty on blades of coarse grass. The eggs are one half inch in diameter, the albumen has considerable firmness, the yolk is one eighth of an inch in diameter, color, greenish olive, paler beneath. I will here omit reciting the development of the embryo previous to the escape of the tadpole from the egg, as there is no essential difference between the development within the egg of the salamander and that of the fish which has been so repeatedly studied with great care and the results recorded with minute exactness.

Fig. 109.

Young of *Amblystoma*, 10th day from the egg. Lower figure of natural size at time of escaping from egg.

The tadpole of this salamander emerges from the egg in twenty-five days. April 25, length one-half inch, color olive, eye spots visible, two short holders, gills rudimentary. May 5, tenth day, eyes developed, irids golden, color greyish olive, with three faint, transverse bands of a darker hue, gills plumed, no holders, fore legs starting; is now active, and feeds voraciously on aquatic insects. May 25, thirty days from the egg, fore feet tridactylous, consisting of thumb, forefinger, which is greatly elongated, and

middle finger a little longer than the thumb. If there should be an arrest of development at this stage, the track would be bird-like. Next, the fourth finger makes its appearance, and, on the hind feet, the fifth comes still later. What is especially interesting is that when the legs or feet have been amputated, which frequently occurs, the operation being performed by those miniature fresh water sharks, the larvæ of dragon flies and water beetles, the development of the toes is precisely in the same order, first the three toes, then the fourth, and on the hind feet the fifth. The gills are now beautifully plumed and when closed reach to the centre of the entire animal; hind legs starting. June 20, fifty-six days, hind feet developed.

As the lungs increase the gills wither and are gradually absorbed, so that by the middle of August the gills have all disappeared. The time consumed in the wonderful process is a little over one hundred days.

## Observations on the Systematic Relations of the Fishes.—By Prof. Edward D. Cope.

### I. PRELIMINARY.

The system of fishes as at present adopted in this country, is the result of the labors of many naturalists, but chiefly of Cuvier, Agassiz, Müller and Gill. Without going into the history of the subject at present, it will be proper to point out the principal modifications of Cuvier's system, introduced by his three successors. The orders of Cuvier were the *Chondropterygii*, *Malacopterygii*, *Acanthopterygii*, *Plectognathi* and *Lophobranchii*.

Professor Agassiz, under the name of *Placoids*, adopted the first division; the second he called the *Cycloids*, the third *Ctenoids*, and then created a fourth order under the name of *Ganoids*, which should embrace a portion of Cuvier's *Chondropterygii* (the sturgeons), a portion of the *Malacopterygii Abdominales* (the bony gars, etc.), and the two last orders of Cuvier. Professor Müller following, with a still more complete anatomical investigation, especially into the soft parts, discerned three *sub-classes* in Cuvier's *Chondrostomi*, which he named the *Leptocardii* (lancelet), *Dermopteri* (lamprey, etc.), and the *Selachii* (sharks, etc.). In the then recently discovered Lepidosiren he saw a fourth sub-class, *Dipnoi*.

Having instituted an investigation of Agassiz' Ganoids, in an able memoir he purged it of the *Plectognath* and *Lophobranchiate* divisions, which are obviously not related to it. These with the *Malacopterygians* and *Acanthopterygians*, he erected into a sixth sub-class, the *Teleostei*. This sub-class containing the greater part of existing fishes, embraced six orders, viz.: *Acanthopteri* (Cuvier's Acanthopterygians), *Anacanthini* (new, for the Cod family, etc.); *Pharyngognathi* (new, for fishes with connate inferior pharyngeal bones); *Physostomi* (Malacopterygians of Cuvier, nearly); *Plectognathi* and *Lophobranchii* of Cuvier. The great number of facts in the anatomy of fishes added by Müller, constitute him the father of modern ichthyology.

Professor Gill, in 1861, adopted many of the divisions of Müller, and rejected some; others were newly proposed. But four sub-classes were recognized, the *Dermopteri*, which includes also Müller's Leptocardii; the *Elasmobranchii*, equivalent to Müller's Selachii; the *Ganoidii*, including here Müller's Dipnoi; and the *Teleostei*. Six orders were attributed to the last sub-class, which were quite different from those of Müller.

Subsequent to this publication, important contributions to the system have been made by Kner, Lütken, Gill, Huxley, etc., which will be noticed at the proper time.

The writer having been engaged in an examination of the osteology of the bony fishes, and general anatomical studies of the whole, has proposed to point out some further modifications of the received system, which he believes will render it a closer reflection of nature. There are some portions of the skeleton which have been to a great extent overlooked in seeking for indications of likeness and difference of types, and the estimation in which many known characters are held, may be much altered on the study of extended material. The skeletons on which the present study is made, are one thousand in number, two hundred belonging to the Academy of Natural Sciences of Philadelphia, and eight hundred to the writer, being the collection made by Professor Joseph Hyrtl, the distinguished anatomist of Vienna. This collection has been long known to anatomists in Europe as the most beautifully and reliably prepared in existence, and as valuable as any for study, on account of the fulness of the representation of the various types.

## II. SPECIAL ON THE GANOIDS.

Recurring to Müller's system, the writer adopts, as characterized beyond dispute, his sub-classes, or orders of LEPTOCARDII, DERMOPTERI, SELACHII and DIPNOI, and confines himself at present to the recent *Ganoidea* and *Teleostei*. I have shared in the doubts occasionally expressed by ichthyologists, as to the essential distinction of these latter divisions, and an examination into the osteology, with reference to this point, confirms the doubts raised by a study of the soft parts. As is well known, Müller distinguished the Ganoidea by the muscular bulbus arteriosus containing numerous valves, and the connection of the optic nerves by commissure rather than by decussation. He added several other characters, knowing them, however, to be shared by various other orders and sub-classes, and I have selected the only two which seemed to be restricted to the division. Their restriction to it, however, is only apparent, and Kner points out that the peculiarity of the optic commissure is shared by some *Physostomi*, and that the difference between the number and character of the valves of the bulbus in Lepidosteus and Amia, is quite as great as that existing between Amia and some of the *Physostomi*. After an examination of the skeleton it is obvious that in this part of the organism also, there is nothing to distinguish this division from the *Teleostei* of Müller. It is true that each of the genera referred to it possesses marked skeletal peculiarities, but they are either not common to all of them, or are shared by some of the *Physostomi*. If, on the other hand, we compare these genera with each other, differences of the greatest importance are observable, which at once distinguish two divisions, one represented by Polypterus, the other by Lepidosteus and Amia.

In the first place the basal radii of the pectoral fins of Polypterus are observed to be excluded from articulation with the scapular arch by the intervention of three elements, which form a pedicel or veritable arm for the fin. In Lepidosteus and Amia the radii are sessile on the scapular arch as in ordinary fishes. The ventral fins present a like difference; the basal radii are long and four in number in Polypterus. In the other two genera they are absent, excepting one rudimental ossicle on the inner basis of the fin (two in *Lepidosteus*) precisely as in the Physostomous families *Mormyridæ*, *Catostomidæ*, etc. If we examine the branchial ap-

paratus, we find an undivided ceratohyal, three branchihyal arches, and no inner and but two outer bones of the superior branchihyals, present in Polypterus. In Lepidosteus and Amia we have the double ceratohyal, four branchihyal arches, with four outer and four inner superior elements, characters of the typical *Teleostei*. The maxillary bone of Polypterus, instead of being free distally, as in fishes generally, is united with an ectopterygoid, and with bones representing, in position at least, postorbital and malar. In the other genera the relations of the maxillary are as in osseous fishes.

The sturgeons (*Accipenseridæ*) agree with Amia, etc., in all of these points but one, differing only in having the superior ceratohyal and several of the superior branchihyals cartilaginous. The one point of distinction is the extension of the basal radial supports of the ventral fin all across its basis as in Polypterus. The pectoral fin is, on the other hand, much as in Lepidosteus. Thus the sturgeons combine in this one respect, the features of both divisions. Both the basal ceratohyals are cartilaginous in this family; the superior only is cartilaginous in Polypterus, Lepidosteus and Amia, while both are ossified in the old *Teleostei*, except in the eels. In these the inferior is cartilaginous, while the superior is coössified to the ceratohyal. Thus in one unimportant character Polypterus agrees with its former associates, but differs more from others of them—the sturgeons, than from the bony fishes.

Another character of both Lepidosteus and Amia betokens a certain relationship to Polypterus, viz., the complexity of the mandible, especially in the possession of a coronoid bone. But here again Accipenser only possess an osseous dentary, while Gymnarchus and Gymnotus have the angular and articular bones distinct from the dentary, wanting the coronoid and opercular. In most bony fishes the angular is not distinct.

It is thus evident that the sub-class Ganoidea cannot be maintained. It cannot be even regarded as an order, since I will show that Lepidosteus, Accipenser, and Amia, are all representatives of distinct orders. I hope also to make it evident that Polypterus should be elevated to the rank of a sub-class or division of equal rank with the rest of the fishes, and with the *Dipnoi* already adopted.

The question may be discussed as to whether naturalists are

correct who regard the fishes as representing variously, from two to four classes. One of these (the Ganoidea), having been already disposed of, it remains to consider the claims of the remainder, viz: The Elasmobranchii (sharks), Dipnoi and typical fishes.

If we examine the points in which the whole taken together differ from the *Batrachia* and other classes above it, we find that it is confined chiefly to the structure of the limbs and the hyoid apparatus. The typical fishes present, however, other important peculiarities, viz.: 1st. The existence of two or three distinct bones in the suspensor of the mandible, instead of one. 2d. The attachment to these of the opercular bones. 3d. The absence of pelvic bones. 4th. The suspension of the scapular arch to the cranium. 5th. The large development of the pterotic (Parker, *mastoid* of Cuvier and Owen) is characteristic of bony fishes.

The types of variation, in the first point, only distinguish groups of subordinate rank. Thus: the suspensor of the mandible in the typical fishes consists of the hyomandibular stapes, quadrate (metapterygoid or incus), symplectic and mesopterygoid (quadratojugal Müller, quadrate Huxley, Elm. Comp. Anat.). In the *Mormyridæ*, *Siluridæ*, *Polypteridæ*, and others, the symplectic is absent; in the eels of several families both it and the metapterygoid are wanting, reducing the suspensorium to a rod of two pieces. This condition exists in many of the rays; in others, and in the sharks, the inferior element is wanting (Müller, Stannius). An important modification is exhibited by Chimæra, where the hyomandibular, which alone exists, is continuous with the cartilaginous cranium, not being separated by the usual articulation.

As to the opercular bones, all are wanting in the Elasmobranchs (sharks and rays) while the typical fishes possess four, viz: preoperculum, operculum, suboperculum and interoperculum. In many of these, however, the suboperculum is wanting, and in the sturgeons and many eels there is no preoperculum. In Polyodon the interoperculum is also wanting. In Lepidosiren the operculum and interoperculum are rudimental. In respect to this point also the divisions indicated are of subordinate value. As regards the development of the pterotic bone, its history is not yet sufficiently made out to enable us to understand its value. It does not exist in those with cartilaginous cranium (*Elasmobranchii*). The Elasmobranchs are well known to have the scapular arch suspended freely behind the cranium as in higher vertebrates. It is not

always attached to the cranium, on the other hand, among true fishes, for in the eels it is quite as in the sharks, and the spinous-finned Mastacembelus presents the same features.

The characters presented by the pelvic bones and limbs seem to be of higher import. Thus all the bony fishes and sturgeons lack all the pelvic elements. In the sharks and rays they are also wanting; but two elements on each side appear in the *Holocephali*, (Chimæra) according to Leydig and Gegenbaur. In Lepidosiren a large median pelvic cartilage exists, but which element it represents is unknown. This is evidently a character of high significance. As to the limbs, the peculiarities of Polypterus have been pointed out above. They mean nothing less than the development of the elements of the arm and leg of the higher vertebrata which intervene between the point of articulation and the distal segments, in Polypterus and the sharks and rays. In the former the distal segments are articulated exclusively to the extremities of the proximal pieces, which thus resemble, as well as represent, humerus and femur, and render the limb pedunculated. The proximal pieces are not continued distally, however, into the representatives of the main axis, which, as demonstrated by the admirable studies of Gegenbaur, consist after humerus, of radius, tarsals and metatarsals, and thumb; in the hind limb, of the line of the tibia and inner toe. This continuation is observed in the Elasmobranchi, where, however, the divergent segments extend along the sides of the proximal pieces to near, in some *Rajidæ* quite, to the articulation with the scapular arch. In the true fishes, including some of the old ganoids already considered, the divergent rays always reach this articulation, while the number of proximal or basal pieces is diminished. These pieces have been called by Gegenbaur the metapterygium (humerus), mesopterygium, and propterygium; the first being axial, the second and third being divergent from it. In Polypterus the propterygium and mesopterygium are largely developed; in sharks and rays the propterygium is sometimes small, sometimes wanting, while in the true fishes the propterygium and mesopterygium are both wanting, excepting in Amia, Lepidosteus, and the sturgeons, where a cartilaginous mesopterygium exists, according to Gegenbaur. This author finds it rudimental in young *Salmonidæ* and *Siluridæ*. Lastly, in the true fishes the distal elements of the axis of the limb are wanting, just as in Polypterus.

In *Dipnoi*, on the other hand, we have this axis complete, or rather with greatly multiplied distal segments, and with or without lateral radii. In the Australian *Ceratodus* Günther finds numerous lateral series on both sides of those of the axial row. Hence the limb of this order is considered by Owen, the simplest or primary type, and this proposition is abundantly confirmed by the beautiful researches of Gegenbaur. The foundation laid by this author for the history of the genesis of limbs will ever be a landmark in the history of *modern theories of creation*. See his memoir, Ueber das Skelet der Gliedmaasen der Wirbelthiere im Allgemeinen, etc., *Jenaische Med. Zeitschr.*, vol. v., p. 397.

Important as are the characters that distinguish the several groups indicated by the different types of structure of the limbs and pelvis, they do not seem to me to warrant their recognition as classes, equivalent to those of the six already pointed out. Taking them together there is a greater coherence also in the structure of brain and circulatory systems than would be the case with any other two of the classes adopted above. The peculiarities of the limbs, important as they are, are nearly related in the want of specialization of their parts, seen in the *Batrachia* and other classes, the differences consisting rather of number and position of similar parts. The pelvis of the *Dipnoi* might be regarded as of primary importance but for its existence in the *Holocephali*, whose limbs again are so near those of the shark.

It remains, therefore, to adopt the Linnæan and Cuvierian class *Pisces*, and to grant as sub-classes, the groups of *Holocephali*, *Selachii* and *Dipnoi*. There remain as sub-classes the groups typified by Polypterus on the one hand, and the true fishes on the other. The first has been already distinguished in its external characters by Professor Huxley, who again brought light out of obscurity when he established his "third sub-order of ganoids, the *Crossopterygidæ*." This division is in my estimation a natural one, and to be elevated to a rank equivalent to that of each of the three above named, being the only part of the original division of Ganoids of Müller entitled to it. Professor Huxley defined it as follows:

"Dorsal fins, two, or if single, multiplied or very long; the pectoral and usually the vertical fins lobate; no branchiostegal rays but two principal, with sometimes lateral and medianjugular plates situated between the rami of the mandible; caudal fin diph-

ycereal or heterocereal; scales cycloid or rhomboid, smooth or sculptured."

Of the above characters that which relates to the lobate fins is the essential one, and is the expression of the external appearance produced by the structure of the bones of the limbs already pointed out by Gegenbaur. The dorsal fins of some families, it is true, possess a remarkable structure, but in Phaneropleuron (Huxley) and some others they appear to be nearly like that of the Dipnoi. The absence of branchiostegal rays is important, but is shared by the sturgeons. The jugular plates appear to exist in Polypterus only among recent fishes, though several, as Amia, Elops, Osteoglossum, etc., possess a median one. Nevertheless, its nature would not lead one to anticipate its being a constant feature in any group of high rank; at least, such is our usual experience with dermal bones. The structures of the skin and scales given by Huxley are very subordinate.

The remaining division answers then to the Teleostei and Ganoidei of Müller, minus Polypterus. The name *Teleostei* cannot be preserved for this division, owing to its entire want of coincidence with that division of Müller, as well as from the fact that the cartilaginous sturgeons must be included in it. I propose, therefore, to call it the *Actinopteri*. The character of the five sub-classes will then be as follows:

CLASS PISCES.

The hyomandibular bone continuous with the cartilaginous cranium, with a rudimental opercular bone. Two distinct pelvic bones on each side. Derivative radii sessile on the sides of the basal bones of the limbs, separated from the articulation. *Holocephali.*

Hyomandibular bone articulated with the cranium; no opercular or pelvic bones. Derivative radii sessile on the sides of the basal bones of the limbs, rarely entering articulation. *Selachii.*

Hyomandibular bone articulated, with rudimental opercular bones; a median pelvic element. Limbs consisting of the axial line only, commencing with the metapterygium and with multiplied segments. *Dipnoi.*

Hyomandibular articulated, opercular bones well developed, a single ceratohyal; no pelvic elements. Limbs having the derivative radii of the primary series on the extremity of the basal pieces, which are in the pectoral fin metapterygium, mesopterygium and propterygium. *Crossopterygia.*

Opercular bones, well developed on separate and complex suspensorium; a double ceratohyal, no pelvic elements. Primary radii of fore limb parallel with basilar elements, both entering the articulation with scapular arch. Basilar elements reduced to metapterygium and very rarely mesopterygium. Primary radii of posterior limbs generally reduced to one rudiment. *Actinopteri.*

### III. ON THE ACTINOPTERI.

In determining the primary types of this sub-class, we return to some characters already mentioned, in which they approximate the *Crossopterygia*, and adding others, follow the various divergences to their specialized terminations.

Thus in Accipenser and allies, the ventral fins possess a complete series of basal radial bones, and the pectorals each a large mesopterygium. In Amia and Lepidosteus the mesopterygium is small, and the basal radii of the ventrals are reduced to their lowest number. In none of them are the basihyals fully developed. Most of the eels retain a character which we have only observed heretofore in the *Selachii.*

We pass by a number of the lower fishes before we find the mandibular arch furnished with a symplectic. One of the most important modifications, which is more or less coincident with a number of others, is that which formed the basis of Bonaparte and Müller's order of *Physostomi.* The presence of the ductus pneumaticus which characterizes it, is always associated with the abdominal position of ventral fins and cycloid scales, and mostly with the presence of the præcoracoid arch, the entrance of the maxillary bone into the border of the mouth and the nonseparation of the parietal bones by the supraoccipital. Yet none of these characters are precisely associated at the point of change in each, for there are physostomous fishes with separated parietals and ctenoid scales (some *Cyprinodontidæ*), and there are *Physoclysti* with abdominal ventrals. Nevertheless, three prominent types stand out in the *Actinopteri*, the sturgeons or *Chondrostei*, the *Physostomi*, and the *Physoclysti*, which may be considered as tribes.

An entire series of basilar segments of the abdominal ventral fins; no branchiostegal rays. *Chondrostei.*

Basilar segments of ventrals rudimental, position of fins abdominal, parietal bones usually united; branchiostegal rays; swim

bladder connected with the stomach or œsophagus by a ductus pneumaticus. *Physostomi.*

No ductus pneumaticus; parietal bones separated by the supra-occipital; ventral fins usually thoracic or jugular; no basilar segments. *Physoclysti.*

CHONDROSTEI.

There are two orders in this division, as follows:

A præcoracoid arch; no symplectic bone; premaxillary forming mouth border; no suboperculum nor preoperculum; mesopterygium distinct; basihyals and superior ceratohyal not ossified; interclavicles present; no interoperculum nor maxillary; branchihyals cartilaginous. *Selachostomi*—The Paddle-fish.

Similar to the last, but with interopercle, maxillary bones, and osseous branchihyal. *Glaniostomi*—The Sturgeons.

The first order embraces the single family of *Spatularidæ*, the second that of *Accipenseridæ*. In both the chorda dorsalis persists, the tail is heterocercal and the osseous cranium is little developed. The basal and radial elements of the limbs, with the coracoids, are not ossified.

PHYSOSTOMI.

The following key will express the leading features of the orders of this division:

I. A præcoracoid arch.

*A.* A coronoid bone.

Maxillary in many pieces; vertebræ opisthocœlian. 3. *Ginglymodi*—The Bony Gar.

Maxillary not transversely divided; vertebræ amphicœlian. 4. *Halecomorphi*—The Dog Fish.

*A A.* No coronoid bone.

* No symplectic bone.

Pterotic simple, anterior vertebræ with ossicula auditus: supra-occipital and parietals coössified. 5. *Nematognathi*—The Cat Fishes.

Pterotic annular, including a cavity closed by a special bone; parietals distinct, vertebræ simple. 6. *Scyphophori*—The Mormyri.

** Symplectic present.

Anterior vertebræ coössified and with ossicula auditus. 7. *Plectospondyli*—The Suckers, etc.

Anterior vertebræ, similar, distinct, without ossicula auditus. 8. *Isospondyli*—Herring, etc.

II. No præcoracoid arch.

*A.* Scapular arch suspended to cranium.

*B.* A symplectic.

Pterotic and anterior vertebræ simple; parietal separated by supra-occipital. 9. *Haplomi*—Pike, etc.

Anterior vertebræ modified; parietals united; pectoral fins. 10. *Glanencheli*—Electric eel.

*B B.* No symplectic.

Anterior vertebræ simple; a præoperculum and maxillary; no pectoral fins. 11. *Ichthyocephali*—Java eels.

*A. A.* Scapular arch free behind the cranium.

**A.* Preoperculum.

A symplectic; maxillary well developed; no pectoral fins. 12. *Holostomi*—Symbranchi.

No symplectic; maxillary lost on connate; pectoral fins. 13. *Enchelycephali*—Eels proper.

** Preoperculum wanting or rudimental.

No symplectic, maxillary, nor pectoral fins, no pterygoid. 14. *Colocephali*—Muræna.

Of the above orders the *Haplomi* (pike, etc.) approach nearest the *Physoclysti* of the families *Opheocephalidæ* and *Atherinidæ;* and the *Holostomi* of the family *Symbranchidæ*, to the Physoclyst family of *Mastacembelidæ*. The affinities between these families is in both cases so close as to render the distinction of the primary divisions in question hardly worth preserving.

The complete development of the support of the caudal fin is seen in many members of this tribe, while in others it remains in its primitive condition. Among *Physoclysti* it is nearly always complete, though in a few (*Trichiuridæ*), etc., it remains larval. In the first development of the vertebral column in fishes, it forms a straight axis. The fin is represented by a fold of the integument which extends equally round its extremity. In this membrane the rays are developed, and in many fishes they remain thus equally distributed. In this case the caudal vertebræ remain in a straight line to the extremity, and we have a termination such as is seen in *Lepidosiren* and the eels. This form of tail may be called the *isocercal*.

If now the radii basal or distal, acquire a greater development

on the lower side of the column, those on the upper side remaining rudimental, it will be necessary that such enlarged portion should strike the water in the plane transverse to the longitudinal axis of the body in order that the weight of the body be propelled with the least expenditure of force. This will necessarily cause the distal vertebræ, or end of the chorda dorsalis, to be turned upward, so that the inferior rays of the fin shall be brought as near to the vertical line of the superior as possible. This is the type of tail known as the *heterocercal*, as called by Agassiz.

We find among the *Physoclysti* that the lower rays of the fin are more and more strengthened, and the hæmal spines which support them, are more and more enlarged. Consequently the end of the column is more curved upwards, as seen in Amia. The superior rays and neural spines are also strengthened, and the inferior so extended upwards as to pass round the extremity of the column and come into contact with them. And now the vertebral centra are successively atrophied from the extremity. Counting from the extremity to the bases of the first supports of the outer rays of the caudal fin above and below, we find that ten vertebræ remain in the tail of Notopterus. In the *Hyodontidæ*, *Albulidæ*, *Elopidæ*, *Alepocephalidæ* and *Salmonidæ*, there are but two left, while one only appears in the *Osteoglossidæ*, *Aulopidæ*, *Lutodiridæ*, *Butyrinidæ*, *Coregonidæ*, *Clupeidæ* and *Chirocentridæ*. In most other families, especially of *Physoclysti*, the last one has disappeared, and the numerous hæmal arches are arranged like radii diverging upwards and downwards from the last caudal vertebra. In the highest groups, as *Pharyngognathi*, etc., they become coössified, and the tail has completed specialization. This is the type called *homocercal* or *diphycercal* by later writers.

These types are thus plainly stages in the development of this member, the first and second being simply arrests of development of the last. Thus the young salmon commences with an eel-like vertebral column, or is *isocercal;* it presently, by the upward curvature of the column, and unequal development of the caudal fin, becomes *diphycercal*, but ceases to grow before it has quite accomplished this stage. The Polypterus, the eels, Gymnarchus and other fishes ossify the vertebræ in the isocercal stage. The heterocercal type is seen in the *Chondrostei*, where the vertebræ never ossify. In Lepidosteus and Amia, they ossify in this stage.

I further specify the characters of the orders of *Physostomi* and the families they contain, in the paper itself.

PHYSOCLYSTI.

The following is an analytic synopsis of the orders. They all have the parietals entirely separated by the supra-occipital, and lack the præcoracoid; the symplectic is present, except in *Ostracium*, where it is not ossified.

*A*. Scapular arch not suspended from the cranium.

Superior branchihyals and pharyngeals developed; inferiors and maxillary distinct. 15. *Opisthomi*.

*A A*. Scapular arch suspended from the cranium.

*I. Ventral Fins Abdominal.*

Branchial arches well developed, the bones present, except fourth superior pharyngeal; third much enlarged; inferior pharyngeals distinct. 16. *Percesoces*—Mullet, etc.

Third and fourth superior pharyngeals much enlarged, inferior pharyngeals, coössified. 17. *Synentognathi*—Soft gar.

Superior branchials and pharyngeals reduced in number; inferiors separate; interclavicles present. 18. *Hemibranchi*—Pipe fishes.

Superior branchihyals and pharyngeals, and basal branchihyals wanting; gills tufted. 19. *Lophobranchi*—Sea horse.

*II. Ventral Fins Thoracic or Jugular.*

First vertebra united to cranium by suture; epiotics united behind superoccipital; basal pectoral radial bones elongate. 20. *Pediculati*—Goose Fish, etc.

Posterior cephalic region normal, anterior twisted so as to bring both orbits on one side; inferior pharyngeals distinct. 21. *Heterosomata*—Flounders.

Cranium normal; the premaxillaries usually coössified with the maxillaries behind, and the dentary with the articular; pharyngeal bones distinct. 22. *Plectognathi*—File Fishes.

Cranium normal; bones of the jaws distinct; inferior pharyngeal bones distinct. 23. *Percomorphi*—Perch.

Cranium normal; bones of the jaws distinct; third superior pharyngeal much enlarged, articulating with cranium; inferior pharyngeals coössified. 24. *Pharyngognathi*—Burgall, Parrot Fish.

These orders will be more fully defined, and the families which are referable to them pointed out.

### GENERAL OBSERVATIONS.

In tracing the affinities of the *Physostomi*, I have pointed out the relation between the *Chrondrostei* and the *Nematognathi*, and between the *Halecomorphi* and the *Isospondyli*. The first named of each of these pairs are the structural, and probably genetic, predecessors of the second. The series commenced with the cat fishes may be continued into the *Mormyri* and then to the families of the *Plectospondyli*, where the series with altered vertebræ and with ossicula auditus terminates. The *Characins* have, however, considerable affinity to the *Isospondyli*, especially in the type of their branchial bones. From the latter group we pass to the *Haplomi*, and thence to the *Physoclyst* groups. The eel-like groups form a special line. The *Glanencheli* have cranial characters of the groups with modified vertebræ, with fins of the more typical eels. The latter show a steady approach in some points to the conditions characterizing the *Chondrostei*. The loss of the maxillary, of opercular bones, and of pharyngeal elements, reminds one of these, but in the loss of the premaxillary, and great development of the ethmoid, in the *Coloçephali*, we have features quite unique. The vertebral position of the scapular arch is the only shark character they possess; while on the other hand, the *Holostomi* are undoubtedly related to the *Mastacembelus*, a real *Physoclyst* with spinous dorsal fin. These relations are as yet entirely inexplicable.

The affinities among the *Physoclysti* are more clear. Omitting the genus just mentioned, we find the four orders with ventral fins to form a true series, with a *Synentognath* variation, terminating in the greatly degraded order of *Lophobranchii*. The *Percesoces* give us our nearest connection with the groups with abdominal ventral fins, and lead at once to the *Percomorphi*. From this centre radiate many lines of affinity. One leads from the *Chætodontidæ*, through the *Acroneuridæ* and to the *Plectognathi*, by the similarity in the arrangement of the posttemporal and forms of the pharyngeal apparatus. An important division of the *Percomorphi* has the basis cranii simple and the branchials reduced above; viz., the *Scyphobranchi*. The *Cottidæ* are the most generalized family of this group, and lead on the one hand to the *Tri-*

*glidæ* of the *Distegi*, with which they are generally arranged, and, on the other, to the *Blenniidæ*. Some of the latter elongate the basal pectoral bones considerably, and lead to the *Batrachidæ* on the one side, where the number of these bones is increased, and on the other to the *Pediculati*, where the number is diminished. To these groups the *Anacanthini* and *Heterosomata* are less allied.

The third upper pharyngeal bone has already presented an increase of mass and use in the first orders of Physoclysti with ventral fins. Among the *Percomorphi* the same increase makes its appearance by little beginnings in some *Sciaenidæ*. It is quite noteworthy in most of the *Carangidæ*, a group whose separation from the *Scombridæ* by Günther is supported by this part of their organism. Through forms not now specified, approach to the *Pharyngognathi* is made. Here the pharyngeals are modified into a mill-like structure, which is least specialized in the *Embiotocidæ*, and most so in the *Scaridæ*.

Mr. F. W. PUTNAM was not prepared to accept all the changes that were proposed by Prof. Cope, some of which were somewhat radical. At the same time, however, he regarded it as the nearest approach to a correct classification of the fishes that had ever been made. The points of distinction between the fishes and batrachians had never been better made, nor in a more unexpected manner. He thought Professor Cope had found the only means by which one can with certainty distinguish a fish from a batrachian. The way in which a number of the families had been grouped together he fully approved of, though some of the groups he thought still open to question.

THE LAWS OF ORGANIC DEVELOPMENT. — BY PROF. E. D. COPE.

THE discussion of this subject divides itself into two parts, viz.: a consideration of the proof that evolution of organic types, or descent with modification has taken place; and, secondly, the investigation of the laws in accordance with which this development has progressed.

I. ON THE PROOF FOR EVOLUTION.

There are two modes of demonstration, both depending on direct observation. One of these has been successfully presented by Darwin. He has observed the origin of varieties in animals and plants, either in the domesticated or wild states, and has shown, what had been known to many, the lack of distinction in the grade of difference which separate varieties and species. But

he has also pointed out that species (such, so far, as distinctness goes) have been derived from other species among domesticated animals, and he infers by induction that other species, whose origin has not been observed, have also descended from common parents. So far I believe his induction to be justified; but when from this basis evolution of divisions defined by important structural characters, as genera, orders, classes, etc., is inferred, I believe that we do not know enough of the uniformity of nature's processes in the premises to enable us to regard this kind of proof as conclusive.

I therefore appeal to another mode of proving it, and one which covers the case of all the more really structural features of animals and plants.

It is well known that in both kingdoms, in a general way, the young stages of the more perfect types are represented or imitated with more or less exactitude by the adults of inferior ones. But a true identity of these adults with the various stages of the higher has, comparatively, rarely been observed. Let such a case be supposed.

In *A* we have four species whose growth attains a given point, a certain number of stages having been passed prior to its termination or maturity. In *B* we have another series of four (the numbering a matter of no importance), which, during the period of growth, cannot be distinguished by any common, *i. e.*, generic character, from the individuals of group *A*, but whose growth has only attained to a point short of that reached by those of group *A* at maturity. Here we have a parallelism, but no true evidence of descent. But if we now find a set of individuals belonging to one species, and therefore held to have had a common origin or parentage (or still better the individuals of a single brood), which present differences among themselves of the character in question, we have gained a point. We know in this case that the individuals, *a*, have attained to the completeness of character presented by group *A*, while others, *b*, of the same parentage have only attained to the structure of those of group *B*. It is perfectly obvious that the individuals of the first part of the family have grown further, and, therefore, in one sense faster, than those of group *b*. If the parents were like the individuals of the more completely grown, then the offspring which did not attain that completeness may be said to have been *retarded* in their develop-

ment. If, on the other hand, the parents were like those less fully grown, then the offspring which have added something have been *accelerated* in their development.

I claim that a consideration of the uniformity of nature's processes, or inductive reasoning, requires me (however it may affect the minds of others) to believe that the groups of species whose individuals I have never found to vary, but which differ in the same point as those in which I have observed the above variations, are also derived from common parents, and the more advanced have been *accelerated* or the less advanced *retarded*, as the case may have been with regard to the parents.

This is not an imaginary case, but a true representation of many which have come under my observation. The developmental resemblances mentioned are universal in the animal and probably in the vegetable kingdoms, approaching the exactitude above depicted in proportion to the near structural similarity of the species considered.

*Example* 1.—It is well known that the *Cervidæ* of the Old World develop a basal snag of the antler (see Cuvier, Ossemens Fossiles, and Gray, Cat. British Museum,) at the third year; a majority of those of the New World (genera Subulo, Cariacus) never develop it except in abnormal cases in the most vigorous maturity of the most northern Cariacus (*C. Virginianus*), while the South American Subulo retains to adult age the simple horn or spike of the second year of all *Cervidæ*.

Among the higher *Cervidæ*, Rusa and Axis never assume characters beyond an equivalent of the fourth year of Cervus. In Dama the characters are, on the other hand, assumed more rapidly than in Cervus, its third year corresponding to the fourth of the latter, and the development in after years of a broad plate of bone, with points being substituted for the addition of the corresponding snags, thus commencing another series which terminates in the great fossil elk, Megacerus.

Returning to the American deer we have Blastocerus, whose antlers are identical with the fourth year of Cariacus. Corresponding with the Dama-Megacerus type of the Old World we have the moose (Alces) developing the same palmate horn on the basis of Cariacus (*i. e.*, without eye-snag.)

*Example* 2.—I select the following series, embracing the majority of the genera of the North American Helicidæ.

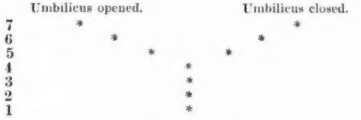
HELICIDÆ.

1. Turns of spire very few; wide umbilicus: shell thin, with thin lips, . . *Binneya.*
2. Turns few, but more; rest as above, . . . . . *Vitrina.*
3. Turns still more numerous; rest as above, . . . . . *Hyalina.*
4. As No. 3, but lip thickened inside, . . . . . *Hygromia.*
5. Coiled; *umbilicus closed:* lip thickened inside and out, . . *Tachea* and *Pomatia.*
6. Same, with a parietal tooth, . . . . . *Mesodon.*
7. Same, with parietal and two interior lip teeth, . . . . . *Isognomostoma.*

* * Recommencing at No. 4. All with open umbilicus.

5. As No. 4, but lip thickened in and out, . . . . . *Arionta.*
6. Same as No. 5, but with parietal tooth, . . . . . *Polymita.*
7. Same, with both parietal and lip teeth, . . . . . *Triodopsis.*

The successional relation of these genera may be represented in such a diagram as this:—




In the history of the growth of the genera Isognomostoma and Triodopsis, the extreme forms of the two series, it is well known that at first the coils of the shell are extremely few, as in Binneya; and that like it, it is very thin and with a delicately thin edge; that the turns increase successively in number, as in Vitrina and Hyalina, and that finally the lip thickens as in Hygromia. Then the umbilicus may close as in Tachea, or (in Triodopsis) remain open as in Arionta. In either case a tooth is soon added on the body whorl (Polymita, Mesodon), and finally, the full maturity of the shell is seen in the added width of the inside of the lip-margin. How many of the stages of the genera *Triodopsis* and *Mesodon* are identical with the genera of the series which represent them I leave to more thorough conchologists, but that some now exhibit and all have presented illustrations of the relation of exact parallelism I cannot doubt.

*Example* 1.—An abundant race of the American deer, *Cariacus Virginianus*, exists in the Adirondack region of New York, in which the development of the antlers never progresses beyond the spike stage of the second year. Therefore, some individuals of this species belong to Cariacus and some to Subulo.

*Example* 2.—A large part of the individuals of the common snail, *Mesodon albolabris*, never develop the tooth of the body-whorl, characteristic of the genus whose definition has to be modified to retain them.

*Example* 3. — Many individuals of *Triodopsis tridentata* from eastern North Carolina occur without the lip-teeth characteristic of the genus *Triodopsis*. Hence these specimens, though of common origin with others of the species, must be referred to another genus.

*Example* 4. — Structural characters are known in many, if not all, species which are said to be "inconstant," being present or absent indifferently, thus being useless for definition. They may be rudimental when present or considerably developed. The presence or absence of wings in some species of insects may be cited; also the presence of generic characters in the male sex of many Coleoptera and their absence in the females. The characters of males, females, workers and soldiers in bees and ants may be added. All these facts belong to the same category as those cited among deer and mollusks and have a similar explanation.

*Example* 5. — It does not seem to be the law in "retardation" that parallelisms exhibited by the series in its rise to its highest point of development should retrace the steps by which it attained it, and that "exact parallelisms" should be exhibited in a reversed order. Parallelisms, it is true, are exhibited; but so far as I have observed always "inexact," often in a high degree. A marked case of retardation occurs in the dental development of a number of persons who have come under my observation in the neighborhood of Philadelphia. It is not very uncommon to find persons in whom the third molars in both jaws are incomplete as to number, one, two, three, or all, being deficient. It is still more common for them to be incompletely covered by the enamel layer, and to become in consequence so worthless as to require early removal. I am acquainted with two families in which the absence of the exterior upper incisor on each side is common. In one of these the second and third generation have inherited it from the mother's side, and it now characterizes many of the children. The significance of this modification will be best understood by examining the dental structures of the *Quadrumana* in general, commencing with the highest family and the modification, we have: —

| | Incisors. | Canines. | Premolars. | Molars. |
|---|---|---|---|---|
| *Hominidæ*, { Abnormal. | $\frac{1}{1}$ | $\frac{1}{1}$ | $\frac{2}{2}$ | $\frac{2}{3}$ |
| *Hominidæ*, { Normal. | $\frac{2}{2}$ | $\frac{1}{1}$ | $\frac{2}{2}$ | $\frac{3}{3}$ |
| *Simiadæ*, | $\frac{2}{2}$ | $\frac{1}{1}$ | $\frac{2}{2}$ | $\frac{3}{3}$ |
| *Cebidæ*, | $\frac{2}{2}$ | $\frac{1}{1}$ | $\frac{3}{3}$ | $\frac{3}{3}$ |
| *Lemuridæ*, | $\frac{3-3}{3-3}$ | $\frac{1}{1}$ | $\frac{3-2}{3-3}$ | $\frac{3}{3}$ |
| *Mammalia*, Normal. | $\frac{3}{3}$ | $\frac{1}{1}$ | $\frac{4}{4}$ | $\frac{3}{3}$ |

In this table we see a decline in the number of teeth of the higher groups. Thus the premolars are one less than the nominal number in the whole order, and they lose one in each jaw in the Old World apes, and man. The molars maintain the normal number throughout, but the third in both jaws is in the *Simiadæ* reduced by the loss of a fifth or odd tubercle, thus becoming four-lobed. In the upper jaw this is first lost in the Semnopithecus; in the lower, in the next highest genus Cercopithecus. In Homo its appearance is "retarded," the interval between that event and the protrusion of the second molar — six to ten years — being relatively greater than in any genus of *Quadrumana*. Its absence is then the result of continued retardation, not of a new and adaptive suppression, and is of direct systematic zoological value.

In the incisors a reduction is also plainly visible, as we pass from the most completely furnished *Lemuridæ* to the genus Homo. One from the upper jaw is first lost, then in the *Cebidæ*, one from the lower also. The number remains the same through the *Simiadæ* and normal *Hominidæ*, but in the abnormal cases cited the process of reduction is continued and another incisor from each side disappears. That this also is truly "retardation" is also evident from the fact that the exterior incisor is the last developed, being delayed in ordinary growth a year later than those of the inner pair. The same retardation is seen in the quadrumane *Cheiromys* (the *Aye-aye*), and the whole order *Rodentia*. In the latter, the rare presence of the reduced second incisors shows that here also the external incisors are lost. This retardation is also of systematic importance, and, should either of the characters described be constant in any of the species of the genus *Homo*, would at once entitle it to new generic rank. The very frequent absence of the posterior molars (wisdom teeth) has been recently found to characterize a race in India. Should this peculiarity prove constant, this race would with propriety be referred to as a new genus of *Hominidæ*, as we have many cases of very similar species being referable to different genera. It is altogether probable that such will, at some future time, be the condition of some race or races of men.

## II. ON THE LAWS OF EVOLUTION.

Wallace and Darwin have propounded as the cause of modification in descent their law of natural selection. This law has been

epitomized by Spencer as the "preservation of the fittest." This neat expression no doubt covers the case, but it leaves the origin of the fittest entirely untouched. Darwin assumes a "tendency to variation" in nature, and it is plainly necessary to do this in order that materials for the exercise of a selection should exist. Darwin and Wallace's law is, then, only restrictive, directive, conservative, or destructive of something already created. Let us, then, seek for the originative laws by which these subjects are furnished —in other words, for the causes of the origin of the fittest.

The origin of new structures which distinguish one generation from those which have preceded it, I have stated to take place under the law of *acceleration*. As growth (creation) of parts usually ceases with maturity, it is entirely plain that the process of acceleration is limited to the period of infancy and youth in all animals. It is also plain that the question of growth is one of nutrition, or of the construction of organs and tissues out of protoplasm.

The construction of the animal types is restricted to two kinds of increase—the addition of identical segments and the addition of identical cells. The first is probably to be referred to the last, but the laws which give rise to it cannot be here explained. Certain it is that segmentation is not only produced by addition of identical parts, but also by subdivision of a homogeneous part. In reducing the vertebrate or most complex animal to its simplest expression, we find that all its specialized parts are but modifications of the segment, either simply or as sub-segments of compound but identical segments. Gegenbaur has pointed out that the most complex limb with hand or foot is constructed, first, of a single longitudinal series of identical segments, from each of which a similar segment diverges, the whole forming parallel series, not only in the oblique transverse, but generally in the longitudinal sense. Thus the limb of the Lepidosiren represents the simple type, that of the Ichthyosaurus a first modification. In the latter the first segment only (femur or humerus) is specialized, the other pieces being undistinguishable. In the Plesiosaurian paddle the separate parts are distinguished; the ulna and radius well marked, the carpal pieces hexagonal, the phalanges well marked, etc.

As regards the whole skeleton the same position may be safely assumed. Though Huxley may reject Owen's theory of the vertebrate character of the segments of the cranium, because they are

so very different from the segments in other parts of the column, the question rests entirely on the definition of a vertebra. If a vertebra be a segment of the skeleton, of course the skull is composed of vertebræ; if not, then the cranium may be said to be formed of "sclerotomes," or some other name may be used. Certain it is, however, that the parts of the segments of the cranium may be now more or less completely parallelised or homologised with each other, and that as we descend the scale of vertebrated animals, the resemblance of these segments to vertebræ increases, and the constituent segments of each become more similar. In the types where the greatest resemblance is seen, segmentation of either is incomplete, for they retain the original cartilaginous basis. Other animals which present cavities or parts of a solid support are still more easily reduced to a simple basis of segments, arranged either longitudinally (worm) or centrifugally (star-fish, etc.)

Each segment — and this term includes not only the parts of a complex whole but parts always subdivided, as the jaw of a whale or the sac-body of a mollusk, — is constructed, as is well known by cell division. In the growing fœtus the first cell divides its nucleus and then its whole outline, and this process repeated millions of times produces, according to the cell theory, all the tissues of the animal organism or their bases from first to last. That the ultimate or histological elements of all organs are produced originally by repetitive growth of simple, nucleated cells with various modifications of exactitude of repetition in the more complex, is taught by the cell theory. The formation of some of the tissues is as follows:

*First Change* — Formation of simple nucleated cells from homogeneous protoplasm or the cytoblastema.

*Second* — Formation of new cells by division of body and nucleus of the old.

*Third* — Formation of tissues by accumulation of cells with or without addition of intercellular cytoblastema.

*A.* In connective tissue by slight alteration of cells and addition of cytoblastema.

*B.* In blood, by addition of fluid cytoblastema (fibrin) to free cells (lymph corpuscles), which in higher animals (vertebrates) develop into blood-corpuscles by loss of membrane, and by cell development of nucleus.

*C.* In muscles by simple confluence of cells, end to end and mingling of contents (Kölliker).

*D.* Of cartilage by formation of cells in cytoblast which break up, their contents being added to cytoblast; this occurring several times, the result being an extensive cytoblast with few and small cells (Vogt). The process is here an attempt at development with only partial success, the result being a tissue of small vitality.

Even in repair-nutrition recourse is had to the nucleated cell. For Cohnheim first shows that if the corner of a frog's eye be scarified, repair is immediately set on foot by the transportation thither of white or lymph or nucleated corpuscles from the neighboring lymph heart. This he ascertained by introducing aniline dye into the latter. Repeated experiments have shown that this is the history in great part of the construction of new tissue in the adult man.

Now, it is well known that the circulating fluid of the fœtus contains for a period only these nucleated cells as corpuscles, and that the lower vertebrates have a greater proportion of these corpuscles than the higher, whence probably the greater facility for repair or reconstruction of lost limbs or parts enjoined by them. The invertebrates possess only nucleated blood corpuscles.

What is the relation of cell division to the forces of nature, and to which of them as a cause is it to be referred, if to any? The animal organism transfers the chemism of the food (protoplasm) to correlated amounts of heat, motion, electricity, light (phosphorescence), and nerve force. But cell division is an affection of protoplasm distinct from any of these. Addition to homogeneous lumps or parts of protoplasm (as in that lowest animal, *Protamœba* of Hæckel,) may be an exhibition of mere molecular force, or addition as is seen in the crystal, but cell division is certainly something distinct. It looks to me like an exhibition of another force, and though this is still an open question, it may be called for the present *growth force*. It is correlated to the other forces, for its exhibitions cease unless the protoplasm exhibiting it be fed. It is potential in the protoplasm of both protoplasmic animal mass and protoplasmic food, and becomes energetic on the union of the two. So long as cell division continues it is energetic; when cells burst and discharge the contained cytoblastema, as in the formation of cartilage, it becomes again potential.

The size of a part is then dependent on the amount of cell division or growth force, which has given it origin, and the number of segments is due to the same cause. The whole question, then, of the creation of animal and vegetable types is reduced to one of the amount and location of growth force.

Before discussing the influences which have increased and located growth force, it will be necessary to point out the mode in which these influences must necessarily have affected growth. Acceleration is only possible during the period of growth in animals, and during that time most of them are removed from the influence of physical or biological causes either through their hidden lives or incapacity for the energetic performance of life functions. These influences must, then, have operated on the parents, been rendered potential in their reproductive cells, and become energetic in the growing fœtus of the next generation. However little we may understand this mysterious process, it is nevertheless a fact. Says Murphy, "There is no act which may not become habitual, and there is no habit that may not be inherited." Materialized, this may be rendered—there is no act which does not direct growth force, and therefore there is no determination of growth force which may not become habitual; there is, then, no habitual determination of growth force which may not be inherited; and of course in a growing fœtus becomes at once energetic in the production of new structure in the direction inherited, which is acceleration.

### III. THE INFLUENCES DIRECTING GROWTH FORCE.

Up to this point we have followed paths more or less distinctly traced in the field of nature. The positions taken appear to me either to have been demonstrated or to have a great balance of probability in their favor. In the closing part of these remarks I shall indulge in more of hypothesis than heretofore.

What are the influences locating growth force? First, physical and chemical causes; second, use; third, effort. I leave the first, as not especially prominent in the economy of type growth among animals, and confine myself to the two following. The effects of use are well known. We cannot use a muscle without increasing its bulk; we cannot use the teeth in mastication without inducing a renewed deposit of dentine within the pulp-cavity to meet the encroachments of attrition. The hands of

the laborer are always larger than those of men of other pursuits. Pathology furnishes us with a host of hypertrophies, exostoses, etc., produced by excessive use, or necessity for increased means of performing excessive work. The tendency, then, induced by use in the parent is to add segments or cells to the organ used. Use thus determines the locality of new repetitions of parts already existing, and determines an increase of growth force at the same time, by the increase of food always accompanying increase of work done, in every animal.

But supposing there be no part or organ to use. Such must have been the condition of every animal prior to the appearance of an additional digit or limb or other useful element. It appears to me that the cause of the determination of growth force is not merely the irritation of the part or organ used by contact with the objects of its use. This would seem to be the remote cause of the deposit of dentine in the used tooth, in the thickening epidermis of the hand of the laborer, in the wandering of the lymph-cells to the scarified cornea of the frog in Cohnheim's experiment. You cannot rub the sclerotica of the eye without producing an expansion of the capillary arteries and corresponding increase in the amount of nutritive fluid. But the case may be different in the muscles and other organs (as the pigment cells of reptiles and fishes) which are under the control of the volition of the animal. Here, and in many other instances which might be cited, it cannot be asserted that the nutrition of use is not under the direct control of the will through the mediation of nerve force. Therefore I am disposed to believe that growth force may be, by the volition of the animal, as readily determined to a locality where an executive organ does not exist, as to the first segment or cell of such an organ already commenced, and that therefore effort is in the order of time, the first factor in acceleration.

Effort and use have, however, very various stimuli to their exertion.

Use of a part by an animal is either compulsory or optional. In either case the use may be followed by an increase of nutrition under the influence of reflex force or of direct volition.

A compulsory use would naturally occur in new situations which take place apart from the control of the animal, where no alternatives are presented. Such a case would arise in a submergence of land where land animals might be imprisoned on an island or

in swamps surrounded by water, and compelled to assume a more or less aquatic life. Another case which has also probably often occurred, would be when the enemies of a species might so increase as to compel a large number of the latter to combat who would previously have escaped it.

In these cases the structure produced would be necessarily adaptive. But the effect would be most frequently to destroy or injure the animals (retard them) thus brought into new situations and compelled to an additional struggle for existence, as has, no doubt, been the case in geologic history. Preservation, with modifications would only ensue where the changes should be introduced very gradually. This mode is always a consequence of the optional use. The cases here included are those where choice selects from several alternatives, thus exercising its influence on structure. Choice will be influenced by the emotions, the imagination, and by intelligence.

As examples of intelligent selection the modified organisms of the varieties of bees and ants must be regarded as striking examples of its exercise. Had all in the hive or hill been modified alike, as soldiers, queens, etc., the origin of the structures might have been thought to be compulsory; but varied and adapted as the different forms are to the wants of a community, the influence of intelligence is too obvious to be denied. The structural results are obtained in this case by a shorter road than by inheritance.

The selection of food offers an opportunity for the exercise of intelligence, and the adoption of means for obtaining it still greater ones. It is here that intelligent selection proves its supremacy as a guide of use, and consequently of structure, to all the other agencies here proposed. The preference for vegetable or for animal food determined by the choice of individual animals among the omnivores, which were, no doubt, according to the palæontological record the predecessors of our herbivores, and perhaps of carnivores also, must have determined their course of life and thus of all their parts into those totally distinct directions. The choice of food under ground, on the ground, or in the trees would necessarily direct the uses of organs in those directions respectively.

Intelligence is a conservative principle and always will direct effort and use into lines which will be beneficial to its possessor. Thus we have the source of the fittest—*i.e.*, addition of parts by increase and location of growth force directed by the will—

the will being under the influence of various kinds of compulsory choice in the lower, and intelligent option among higher animals. Thus intelligent choice may be regarded as the originator of the fittest, while natural selection is the tribunal to which all the results of accelerated growth are submitted. This preserves or destroys them, and determines the new points of departure on which accelerated growth shall build.

Acceleration under the influence of effort accounts for the existence of rudimental characters. Many other characters will follow at a distance, the modifications proceeding in accordance with the laws here proposed, and retardation is accounted for by complementary or absolute loss of growth force.

Prof. GRAY, Prof. SWALLOW, Dr. HILGARD, Mr. PUTNAM, and others participated in the discussion of this paper.

THE following papers were also read in SECTION B, but the authors have failed to send us abstracts: —

A Theory on the Nature of the Difference in the Mental Capacity of High and Low Races of Men.— By Mr. RENAS DAVIS.
Observations on the Geology, Physical Features and Retrocession of Niagara Falls.— By Mr. GEORGE W. HOLLEY.
Contributions to Physigraphic and Dynamical Geology.— By Prof. RICHARD OWEN.
On the Phyllotaxis of the Cucurbitaceæ.— By Mr. H. W. RAVENEL.
Remarks on the Geology of the Mississippi Bottom.— By Dr. E. A. SMITH.
Remarks on the Catskill Red Sandstone Group as it occurs upon the borders of New York and Pennsylvania.— By Prof. JAMES HALL.
Remarks on the Snow Line in the Mountains of Montana.— By Prof. G. C. SWALLOW.
Some Observations on the Geology of Ohio.— By Prof. E. B. ANDREWS.
Notice of Tertiary Insects found by F. C. A. Richardson on the Green River in Wyoming.— By Prof. J. H. MCCHESNEY.
On Fossils and Minerals from North Carolina.— By Prof. W. C. KERR.

THE following were read by title only: —

The Classification of Echinoderms from their Microscopic Structure.— By Mr. A. AGASSIZ.
Observations on the Common Ground Worm.— By Mr. JAMES J. H. GREGORY.
Some Questions on Surface Geology.— By Prof. FRANK H. BRADLEY.
On the Entozoa Peculiar to Swine.— By Dr. W. B. FLETCHER.
On the Apparently One-ranked Phyllotaxis of Baptisia perfoliata.— By Mr. H. W. RAVENEL.
On the Geology of Northwestern Massachusetts.— By Prof. SANBORN TENNEY.
Remarks on the Cinnabar and other Minerals from California.— By Prof. J. LAWRENCE SMITH.
Remarks on the Abies Douglassii and a new Species, or a peculiar variety of Abies balsamifera of the Rocky Mountains.— By Prof. G. C. SWALLOW.
On some of the results in Geology and Palæontology of the Geological Survey of Ohio.— By Prof. J. S. NEWBERRY.
The Lignites of the West: their Geology and Economic value.— By Prof. J. S. NEWBERRY.
On the Homologies of the Rays of the Dorsal Fins of Polypterus.— By Prof. E. D. COPE.

THE following were given as lectures at the General Sessions held at Terre Haute: — "On the Fertilization of Flowers by Insect Agency," by Prof. ASA GRAY. "On the Pterosauria," by Dr. B. WATERHOUSE HAWKINS.

Dr. T. STERRY HUNT also delivered a lecture at Indianapolis, "On the Coal and Iron Resources of Indiana," and Prof. E. S. MORSE gave a lecture at a general session in Indianapolis, "On some of the Common Animals."

THE following papers, presented before SECTION A, were also of special interest to members of SECTION B: —

On the Rainfall in the United States.— By Prof. JOSEPH HENRY.
On the Dust Storm which occurred in Clinton Co., Ind., Dec. 24, 1870.— By Prof. J. TINGLEY.
On a new form of Boomerang in use among the Magni Puebla Indians of North America.— By Dr. C. C. PARRY.
The Character and Chemical Composition of the Meteorite that fell in May, near Searsmont, Me.— By Prof. J. LAWRENCE SMITH.

Description of the exact Locality of the immense masses of Meteoric Iron in Cahuila, Mexico, with the analysis of one recently discovered.—By Prof. J. LAWRENCE SMITH.
On Dentistry as practiced by the Romans 600 years B. C.—By Dr. EZRA READ.

THE following abstracts of remarks, made in connection with several papers, are of sufficient interest to print, though the papers to which they should have been appended do not appear owing to our failing to receive abstracts from their authors:—

Prof. E. W. HILGARD remarked, in the discussion of the paper by Dr. Smith on the "Mississippi Bottom," that his own observations in the Tensas bottom, in Louisiana, confirmed those of Dr. Smith. Much of the best land there, is a genuine prairie soil, full of calcareous concretions—a feature entirely foreign to the true river alluvium as well as the modern paludal deposits. These calcareous concretions appear to result from the maceration and dissolution of the fossil shells, as distinctly observed in several localities; and are very characteristic of the lower portion of the Port Hudson beds. There can be no doubt that a very large portion of the celebrated "alluvial" lands of the lower Mississippi are no alluvium at all, but substantially result from the disintegration of these older beds.

During the discussion on Prof. Andrews' paper on the "Geology of Ohio," the following remarks were made:—

Prof. A. WINCHELL remarked that he had examined the boulder-like stone taken by Professor Andrews from a coal bed in Ohio and felt very confident that it was a genuine boulder of Carboniferous times. The fragment showed that the rock had been a smoothed and rounded fragment of quartzite, composed of glassy and smurky grains of quartz, and that in every respect it was undistinguishable from surface boulders of Huronian quartzites, so abundant throughout the north. It was a very interesting phenomenon, since, so far as he remembered, it was the first instance of the discovery of a boulder in a bed of bituminous coal. It need not surprise us, however, because geologists well know that from the beginning to the end of the Coal-measure epoch, there were frequent intervals during which agencies existed which overspread portions of the sea-bottom with rounded quartzose fragments, evidently transported from the far north. Whatever these agencies were, it would not be unlikely that an occasional boulder should become mingled with the vegetable and alluvial materials quietly accumulating for the formation of a future bed of coal.

Dr. C. A. WHITE said he could not detect the presence of any hornblende in this piece of rock under his lens. It seems to be only a quartzite, similar masses of which he had often found in the coal-measures of Iowa. He had seen masses of quartzite imbedded in the very soft impure sandstones of the lower Coal-measures there, which had evidently been formed as quartzite just where they are, as the lines of stratification pass continuously through the soft sandstone and the quartzite lumps. The manner in which these quartzite masses, great and small, have originated need not now be discussed, but it is certain that they did originate where we now find them. He could not help regarding this mass as having a similar origin.

During one of the general discussions, Prof. A. H. WORTHEN said that the vertical range of the remains of the mammoth and mastodon is an interesting question; and bearing upon that I will relate the circumstances attending the discovery of the bones found between Illiopolis and Niantic, in Macon Co., in Illinois, in September, 1870. A farmer while digging a shallow well, to obtain water for the supply of stock, in a low peaty bog, at the depth of four feet below the surface, came upon what proved to be an entire tusk of a mastodon. This tusk was

nine feet in length, and eight inches in diameter at the largest extremity, and entirely perfect. In addition to this, he obtained about two-thirds of the other tusk, the lower jaw, with the teeth all remaining in their places, the teeth of the upper jaw, and also some fragments of other bones of the same animal. With these were found a pair of the antlers of a large elk, with some other bones of the same animal, and also bones of the buffalo and deer. These were all embedded in a quicksand containing Physa, Planorbis, and Cyclas, of existing species, and beneath four feet of black peaty soil.

There are, in the Illinois State Collection, some other remains of this kind, which have been found in older deposits, among which are fragments of two mammoths found in true Drift, and bones of another specimen of mastodon found in the vicinity of Morris, in Grundy County, in undisturbed Drift, at a depth of eight feet below the surface, so that these extinct animals seemed to have lived in Illinois down to a comparatively recent period. At Alton, Illinois, a jaw of a mastodon, with both teeth remaining in place, was found at the base of the Loess, thirty feet below the surface.

THE meetings of SECTION B were well attended, and the members while feeling the necessity for fuller discussions of many papers, forebore to do so on account of the limited time for critical work in the section.

The officers of the section were Prof. C. G. SWALLOW of St. Louis, *Permanent Chairman;* Mr. J. E. EMERTON of Salem, *Secretary;* Professors COPE, MORSE and MARCY, *Sectional Committee.*

## SUBSECTION (OF SECTION A.) MICROSCOPY.

THE Subsection of Microscopy renewed its organization by the election of the following officers: *Chairman*, Prof J. E. HILGARD of Washington; *Secretary*, Dr. W. W. BUTTERFIELD of Indianapolis; *Sectional Committee*, Messrs. WARD, BICKNELL and TUTTLE.

The attendance was smaller than at the two previous meetings, but the papers and discussions presented some points of unusual interest. The abstract of Prof. Ward's paper is the only one we have received in time for publication in this number.

Among the novelties of apparatus may be noticed the observation of the electric induction spark by the micro-spectroscope, by Prof. Vander Weyde; the oblique illumination of transparent objects under high powers by means of light reflected from a plane mirror lying upon the stage and directly beneath the mounted object—a little expedient of great practical convenience, also by Prof. Vander Weyde; the adoption of the Wenham Binocular arrangement by Zentmayer; and the somewhat general introduction into use of the eye-piece condensers with a wide horizontal illumination (for binoculars) upon the plan proposed by Prof. Ward at the Troy meeting last summer, and published in the NATURALIST of Dec., 1870. Mr. Bicknell places the stop-plate between the lenses of the condenser, instead of below them; and Prof. Ward, while retaining the eye-piece arrangement for use with low powers, for high powers combines the centring adjustment, Iris diaphragm, and stop-plate, with an achromatic combination of larger angle and more perfect corrections.

The committee on uniform standards in the powers of objectives and eye-pieces being unprepared to report, Messrs. Ward and Bicknell reported verbally, and the committee was continued until the next meeting. While an exact uniformity in the amplifying power of lenses in the same denomination is not to be looked for, it is believed that much of the existing confusion may be remedied. Many microscopists, the speakers among the number, have long been accustomed to alter the denomination of their lenses so as to represent, as nearly as practicable, their amplifying power when in actual use; and probably the principal makers in this

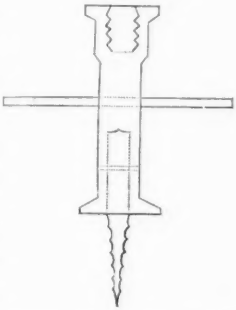
country will freely coöperate with microscopists attaining this very desirable result. The introduction already partially accomplished, of a grading of the eye-pieces by comparison with equivalent single lenses, 2in., 1 in., ½ in., etc., may render this part of the subject, which seemed almost unattainable, the easiest and first to be accomplished. The remarks on the subject of powers will be given in a future number of the NATURALIST.

ON A NEW MICRO-TELESCOPE. — BY PROF. R. H. WARD.

THIS is designed especially for travelling and field use, but applicable to some of the daily work of the microscopist. It consists of a stand and accessories as follows: (A) An ordinary Tank Microscope having the body focussed by a rack and clamped at any desired height upon a stand like that of the bull's eye condensers. Probably few naturalists have any suspicion of the real usefulness of this little piece of apparatus, not only in the study of objects living in an aquarium or preserved in alcohol, glycerine, etc., but for the hasty inspection of herbarium specimens permanently fastened upon sheets of paper too large for the stage of an ordinary microscope, and for the preliminary examination of objects in jars, boxes, dissecting troughs, etc. The writer always keeps upon his working table such an instrument carrying a double nose-piece (the crooked form) and usually one-inch and three-inch objectives, and uses it continually and with great satisfaction as a substitute for a simple microscope. The brass foot-plate at the bottom of the upright pillar should be made somewhat larger and heavier than usual. (B) A Stage of convenient size and simple construction, sliding upon the upright pillar and capable of being clamped securely in any position. This stage carries a diaphragm and mirror below and stage forceps above, and enables the instrument to be used as a vertical compound microscope for ordinary work when, as in travelling or on a field-day, no more commodious stand may be available. This combination may also be used as a dissecting microscope, though for that purpose it is greatly preferable to use the Tank Microscope as a magnifier only, and to place the object, if opake, on the table, or if transparent, on the stage of any good dissecting microscope that may be within reach. (C) A Draw Tube sliding over the compound body from below, and capable of being fastened by a bayonet catch to the brass-work through which the compound body is moved by the rack. The objective in the compound body now acts as an erector, and another is to be screwed, by means of a large adapter, into the lower end of the Draw Tube, to act as the objective.

The rack-movement now only varies the power, and may be thus used as a fine adjustment, while the coarse adjustment must be gained by moving the whole instrument. This combination is extremely useful for dissecting, its greatest misfortune being that it is a monocular arrangement. (D) A Telescopic Object Glass of one inch linear aperture and four inch solar focus, to be screwed, instead of the objective, into the bottom of the Draw Tube. To this Object Glass the compound body with its eye-piece and objective acts as an erecting eye-piece, and is focussed by means of its rack-movement. This combination gives a telescope of good working qualities, and of power entirely disproportioned to its size. (E) A brass Pillar (Fig. 110) about two inches long, having a steel transverse bar for a handle, and at its lower end a gimlet-screw to be fastened into a tree, post, or board. Into its upper end may be screwed the upright pillar of the Tank Microscope. The gimlet screw may be made of steel, which is somewhat durable, or a common iron screw may be used, which easily wears out but can be replaced at a nominal expense. This fixture adapts the instrument to field use, as a microscope or telescope.

Fig. 110.



This instrument should be furnished with a compressor and two objectives,—a one-inch and a two-inch, two-thirds inch, one-half inch, or four-tenths inch, according to the wants of the owner. Either of these objectives may be used as an erector, though the higher ones will seldom be preferred for this purpose. The four or five inch objective usually furnished with tank microscopes may well be dispensed with, as its effect is easily gained by means of the erecting arrangement. Microscopists who have laid aside the ordinary "erector" of the shops as an entirely unsatisfactory affair, need not, on that account, expect a similar failure in the use of a good one-inch or two-inch objective as an erector.

The cost of this instrument ought not to be large. It should not exceed sixty or seventy dollars to those already supplied with objectives and compressors, or one hundred dollars, complete.

THE following papers were also read in the Subsection of Microscopy:

Report on Photographing Histological Preparations by Sunlight.— By Dr. J. J. WOODWARD.
Remarks on a new form of Achromatic Condenser.— By Mr. E. BICKNELL.

Remarks on recent improvements in Achromatic Condensers.—By Prof. R. H. WARD.
On the use of the Microscope in Chemical Analysis.—By Prof. P. H. VANDER WEYDE.
On the observation of the Electric Induction Spark by the Micro-spectroscope.—By Prof. P. H. VANDER WEYDE.
On Oblique Microscopic Illumination, and a new simple Apparatus for the same.—By Prof. P. H. VANDER WEYDE.
On some observed changes in Vorticella.—By Mr. A. H. TUTTLE.
On a Standard of Powers for Microscopical Objectives and Eye Pieces.—By Prof. WARD.
On the Microscopic Structure of Eozoon Canadense.—By Mr. E. BICKNELL.

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GENERAL OFFICERS OF THE INDIANAPOLIS MEETING.

*President*, Prof. ASA GRAY of Cambridge; *Vice President*, Prof. G. F. BARKER of New Haven; *Permanent Secretary*, Prof. JOSEPH LOVERING of Cambridge; *General Secretary*, F. W. PUTNAM, A.M., of Salem; *Treasurer*, WM. S. VAUX, Esq., of Philadelphia; *Standing Committee* present:—Messrs. GRAY, BARKER, LOVERING, PUTNAM, HUNT, J. L. SMITH, SWALLOW, HALL, J. E. HILGARD, WINCHELL, COX, LAPHAM.

ONE hundred and seven papers were entered, of which thirty-two were read in full in Section B, and eleven by title; ten were read in Subsection of Microscopy; thirty in full in Section A, and seven by title; two in the General Session; and fifteen were not entered on the daily programmes.

The first morning (Wednesday, Aug. 16) was given to organization, the work of the sections commencing in the afternoon. In the evening the retiring president, Dr. Hunt, gave his address, and resigned the chair to the president elect. Friday and Saturday were given to the excursion to the coal field of Clay county, and to Terre Haute, where the Association was most cordially welcomed. The town of Brazil also welcomed the Association on the trip to the coal field, which with several other cordial greetings, extended either to the Association as a body, or to small numbers of its members, evinced the hearty appreciation in which the objects of the Association were held by the inhabitants of Indiana. The local secretary, Prof Cox, the officers at the State House, and citizens who took a part in the reception, have left the Association in debt to them for their untiring efforts and generous welcome.

Of the Mammoth Cave and the Ancient Mounds on the Wabash, visited after the adjournment, we shall have papers in future numbers.

The invitation to hold the next meeting in San Francisco was renewed by letter from the Board of Trade and the Academy of Sciences, and was accepted provided the necessary arrangements could be made.

The invitation from Dubuque was accepted conditionally to that of San Francisco. Invitations to hold future meetings of the Association in the following cities were received: Pittsburg, St. Louis, Ann Arbor, and Leavenworth.

A Committee on the Geological Survey of Missouri, and one relating to Observations to be made at Niagara Falls, were appointed.

OFFICERS ELECTED FOR THE MEETING OF 1872.

*President*, Prof. J. LAWRENCE SMITH of Louisville; *Vice President*, Prof. ALEX. WINCHELL of Ann Arbor; *Permanent Secretary*, Prof. JOSEPH LOVERING of Cambridge; *General Secretary*, Prof. E. S. MORSE of Salem; *Treasurer*, Wm. S. VAUX, Esq., of Philadelphia; *Auditing Committee*, Dr. H. WHEATLAND of Salem and Professor H. L. EUSTIS of Cambridge; *Standing Committee Ex Officio*, Messrs. SMITH, WINCHELL, LOVERING, MORSE, VAUX, GRAY, BARKER, PUTNAM.

Committee from the Standing Committee to arrange for next meeting: Profs. J. L. SMITH, ASA GRAY, JOSEPH LOVERING, in connection with a committee from the Association at large, consisting of Profs. J. L. SMITH, J. D. WHITNEY and O. C. MARSH.

The Association adjourned on Tuesday night, August 22d.